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MSFN RELIABILITY FOR A LUNAR LANDING MISSION

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MSFN RELIABILITY FOR A LUNAR LANDING MISSION

May, 1969

Goddard Space Flight Center
Greenbelt, Maryland

MSFN RELIABILITY
FOR
A LUNAR LANDING MISSION

Prepared by

Applied Physics Laboratory
Contract NOw 62-0604C Task N

Under Technical Direction of
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May, 1969

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FOREWORD
by
F. Kalil

This report is the second in a series of reports to be presented by the Applied Physics Laboratory (Contract NOw 62-0604-C, Task N), regarding the reliability of the Manned Space Flight Network (MSFN). The reliability analyses contained herein are based primarily on failures experienced during flight support status. Previous analyses and predictions of MSFN reliability for supporting the lunar orbiting mission (Apollo 8, AS-503) were reported[1] prior to the mission. These latter predictions correlated with the actual experience during the AS-503 mission. This report presents similar predictions about the MSFN reliability for supporting the forthcoming lunar landing, which is scheduled for July, 1969. The reliability predictions contained herein differ from the previous ones[1] in that these predictions: (1) incorporate data from a larger number of missions; and (2) consider the fact that two manned vehicles must be supported simultaneously during the phases when the LEM descends, lands and stays on the lunar surface, ascends, and docks with the CSM. These phases put the MSFN to a more severe use; however, the predictions herein indicate that the MSFN will be able to successfully support the mission. Although the reliability predictions are contained in the body of the report, they are repeated here in summary form (Tables I and II) for completeness and emphasis. The mission phases referred to in Tables I and II are diagrammatically depicted in the following Figure-a.

As shown in Tables I and II, the MSFN's reliability is predicted to be ~0.999 for each of the support functions during each phase of a lunar landing mission. Redundancy in both hardware and mission coverage were considered, and all failures (hardware, software, and operator) were considered. The single site availability is predicted to be ~0.86 on the average for each of the support functions listed for the earth orbital phases; however, the availability for each of the functions approaches ~0.997 shortly after translunar injection when three or more stations are in view of the spacecraft. It should be noted that the availability of ~0.86 for a single site could be misleading, primarily because not each site must necessarily support every function in the earth orbital phase to insure success of the mission. For instance, MIL, GBM, and GBI provide redundant coverage during the launch phase; and the network provides 17 contacts, about 7.5 minutes each, via individual stations during the first two orbits of the earth packing orbit phase for check-out of the spacecraft systems.

[1]"Performance Evaluation of the Unified S-Band Ground System for AS-205," GSFC report X-834-68-485, Dec. 1968.

Table I. Summary of Lunar Mission Functional Support Reliability

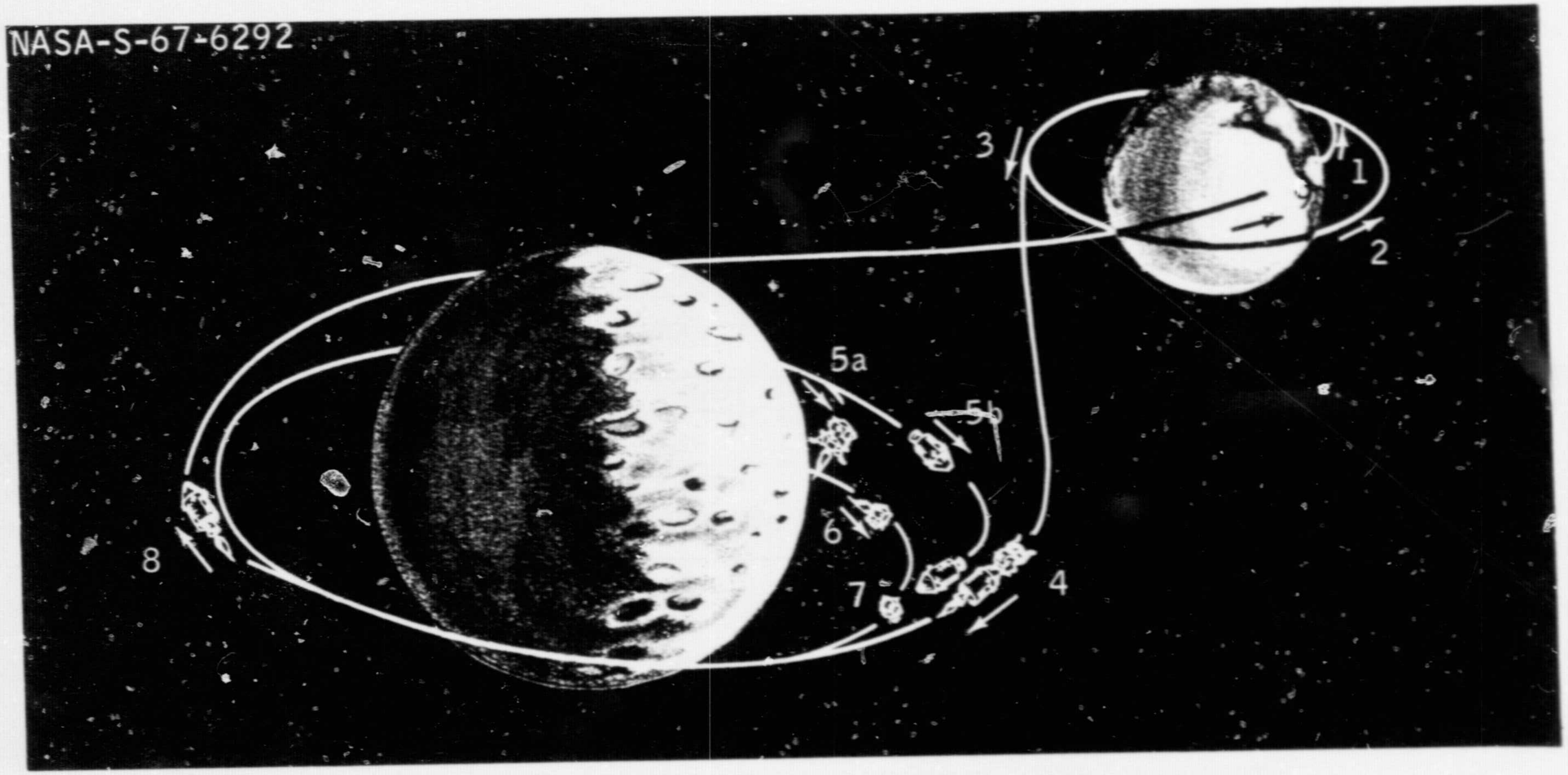
Mission Phase	I) Determine Position of Spacecraft(s) vs Time (tracking/navigation)		II) Maintain Voice Communication with Spacecraft(s)		III) Monitor Spacecraft(s) Status and Systems (telemetry/television)		IV) Send Commands/other Up Data to Spacecraft(s)	
	Single Site MTBF	Reliability (Multiple Site Coverage)	Single Site MTBF	Reliability (Multiple Site Coverage)	Single Site MTBF	Reliability (Multiple Site Coverage)	Single Site MTBF	Reliability (Multiple Site Coverage)
Launch, Insertion, Earth Parking Orbit	119 hrs	0.99893	424 hrs	0.99982	107 hrs	0.99876	127 hrs	0.99925
Translunar Injection, Transposition and Docking	119 hrs	0.99975	424 hrs	0.99999	107 hrs	0.99964	127 hrs	0.99976
Translunar* Flight	119 hrs	0.99731	191 hrs	0.99995	107 hrs	0.99636	127 hrs	0.99751
Lunar Stay,* LM; Lunar Orbit CSM	119 hrs	0.99731	191 hrs	0.99995	107 hrs	0.99636	127 hrs	0.99751
Transearth Flight	119 hrs	0.999978	191 hrs	0.999999*	107 hrs	0.999962	127 hrs	0.999981
Entry	119 hrs	0.99893	424 hrs	0.99982	107 hrs	0.99876	127 hrs	0.99925

*Two spacecraft

Table II. Summary of Lunar Mission Functional Support Availability

I) Determine Position of Spacedraft(s) vs Time (tracking/navigation)		II) Maintain Voice Communication with Spacecraft(s)		III) Monitor Spacecraft(s) Status and Systems telemetry/television)		IV) Send Commands– other Up Data to Spacecraft(s)	
Single Site Availability	Availability (Multiple Site Coverage)*	Single Site Availability	Availability (Multiple Site Coverage)*	Single Site Availability	Availability (Multiple Site Coverage)*	Single Site Availability	Availability (Multiple Site Coverage)*
0.86	$0.997 \leq A$	0.92	$0.999 \leq A$	0.86	$0.997 \leq A$	0.83	$0.995 \leq A$

*Three or more sites will see the spacecraft simultaneously after transposition and docking.



1 Launch into earth orbit
2 Earth orbital checkout
3a Inject into trajectory toward moon
3b Transposition and docking
4 Deboost into lunar orbit
5a LM descent to surface
5b CSM continues in lunar orbit
6 LM ascent
7 Rendezvous and docking
8 Inject CSM into trajectory toward earth
9 Separate CM, enter atmosphere, and land

Figure a—Typical lunar landing mission.

LUNAR LANDING MISSION RELIABILITY STUDY

1. Introduction

A study has been done to estimate the mission support function reliability of the Manned Space Flight Network for a lunar landing mission. This is a follow up effort to a previous study done for a lunar orbital mission. The lunar orbital mission study was submitted to the Manned Flight Planning and Analysis Division (MFPAD) at Goddard Space Flight Center in early December, 1968. The lunar orbital mission study was also included in the October-December 1968 Quarterly Progress Report of the Manned Space Flight Network Study Program (Reference 1). This is the quarterly progress report by the Space Communications Group (CSC) of the Johns Hopkins University/Applied Physics Laboratory.

The present study extends previous work in several areas:

(1) A more complex mission profile is considered with additional mission phases such as "transposition and docking," "lunar module descent and landing" included. The most significant additional complexity, from a MSFN reliability standpoint, is that during much of the mission, coverage must be provided for two spacecraft.

(2) Failure and repair data for 5 missions has been utilized in compiling the reliability estimates. This data has been obtained from NOM and MMR mission status reporting for the AS-501, AS-204, AS-502, AS-503, and AS-205 missions. The last two listed missions provided data not available for the previous study. For the AS-503 and AS-205 missions it was necessary to reduce the data directly from the station submitted TWX reports since no post mission problem summaries were provided as had been done for the three earlier missions.

(3) A summary tabulation of "Availability" is included in addition to summary and detailed tabulations of "Reliability." This is done to estimate, under certain assumptions, the effect of site down time. A discussion of the interpretation of "Availability," how it differs from "Reliability," and the assumptions made in determining the estimates is given in Sections (2) and (3).

Equipment failure data was translated into functional support reliability estimation by interconnecting, from a reliability standpoint, those equipments necessary for the support of the function assumed. Equipment redundancy and multiple site coverage were taken into account.

2. Summary of Results

Table I is a summary tabulation of site mean time between failure (MTBF) and overall Reliability via multiple site coverage for the four major MSFN support functions during each phase of the mission. Table IV is a more detailed tabulation of the same information with major support functions broken down into subfunctions.

The list of required support functions assumed for this study is given in Figure 1. The tables show that no functional MTBF, as estimated from the data, is less than 107 hours for a single site.

The reliability estimates are obtained from the MTBF estimate, an exponential failure law assumption, and a weighted combination of the site coverage time interval and number of sites covering depending upon mission phase. These reliability estimates give the probability of failure free support over a time interval by at least one site out of the total number of covering sites. The coverage time interval and number of sites covering depend upon mission phase.

Table II is a summary table of single site and multiple site coverage Availability for the four major MSFN support functions. These estimates are approximations which take into account the ratio of average repair time to mean time between failure for each equipment area and the amount of equipment required to support each function. The interpretation of these availability estimates differs from that of reliability in that reliability is a time dependent probability of failure free operation given that the time interval began with the site in the "up" state. Availability is an asymptotic or "steady state" probability of being in the "up" state after some time has passed and does not depend upon the state of things at the beginning of the time interval if a sufficiently long time interval is considered. This asymptotic probability (availability) is reached after a period of time has passed during which both failures and repairs have occurred. The estimates can be interpreted as measuring the probability of, at any arbitrary time during the mission, finding a site (or at least one of 3 sites) capable of supporting the function.

The estimates of reliability and availability can both be of interest from different viewpoints. Reliability is of more concern when a relatively short interval of time is considered during which it is essential that no failures occur. Availability is of more concern when a longer period of time has passed over which it is likely that failures (and hopefully rapidly completed repairs) have occurred and the probability of finding a site "up" is considered.

Table I. Summary of Lunar Mission Functional Support Reliability

	I) Determine Position of Spacecraft(s) vs Time (tracking/navigation)		II) Maintain Voice Communication with Spacecraft(s)		III) Monitor Spacecraft(s) Status and Systems (telemetry/television)		IV) Send Commands/ other Up Data to Spacecraft(s)	
Mission Phase	Single Site MTBF	Reliability (Multiple Site Coverage)	Single Site MTBF	Reliability (Multiple Site Coverage)	Single Site MTBF	Reliability (Multiple Site Coverage)	Single Site MTBF	Reliability (Multiple Site Coverage)
Launch, Insertion, Earth Parking Orbit	119 hrs	0.99893	424 hrs	0.99982	107 hrs	0.99876	127 hrs	0.99925
Translunar Injection, Transposition and Docking	119 hrs	0.99975	424 hrs	0.99999	107 hrs	0.99964	127 hrs	0.99976
Translunar* Flight	119 hrs	0.99731	191 hrs	0.99995	107 hrs	0.99636	127 hrs	0.99751
Lunar Stay,* LM; Lunar Orbit CSM	119 hrs	0.99731	191 hrs	0.99995	107 hrs	0.99636	127 hrs	0.99751
Transearth Flight	119 hrs	0.999978	191 hrs	0.999999*	107 hrs	0.999962	127 hrs	0.999981
Entry	119 hrs	0.99893	424 hrs	0.99982	107 hrs	0.99876	127 hrs	0.99925

*Two spacecraft

I Determine Position of Spacecraft vs Time (Tracking/Navigation)
- A) Receive Position/Time Data from MCC or MSFN
- B) Acquire and Track Spacecraft and its Signals
- C) Transmit Spacecraft Position/Time to MCC
- D) Record Spacecraft Position/Time at Site

II Maintain Voice Communications with Spacecraft
- A) Receive voice from MCC
- B) Transmit voice to spacecraft
- C) Receive voice from spacecraft
- D) Transmit voice to MCC
- E) Record voice on site

III Monitor Spacecraft Status and Systems
- A) Receive telemetry from spacecraft
- B) Process and transmit telemetry summaries to MCC
- C) Record telemetry on site
- D) Receive Television from spacecraft

IV Send Commands/other Up Data to Spacecraft
- A) Receive commands MCC
- B) Process command data
- C) Transmit up data to spacecraft
- D) Verify that up data is transmitted
- E) Verify that up data is received
- F) Transmit command verification to MCC
- G) Record command history on site

V Maintain Site Proficiency
- A) Test and maintain systems performance
- B) Maintain voice communication with MCC and MSFN
- C) Maintain teletype communication with MCC and MSFN
- D) Maintain data communication with MCC and MSFN
- E) Monitor and maintain all fundamental power equipment
- F) Receive and originate documents and reports

Figure 1–List of Mission Support Functions for each MSFN Site

Table II. Summary of Lunar Mission Functional Support Availability

I) Determine Position of Spacedraft(s) vs Time (tracking/navigation)		II) Maintain Voice Communication with Spacecraft(s)		III) Monitor Spacecraft(s) Status and Systems telemetry/television)		IV) Send Commands– other Up Data to Spacecraft(s)	
Single Site Availability	Availability (Multiple Site Coverage)*	Single Site Availability	Availability (Multiple Site Coverage)*	Single Site Availability	Availability (Multiple Site Coverage)*	Single Site Availability	Availability (Multiple Site Coverage)*
0.86	$0.997 \leq A$	0.92	$0.999 \leq A$	0.86	$0.997 \leq A$	0.83	$0.995 \leq A$

*Three or more sites will see the spacecraft simultaneously after transposition and docking.

3. Outline of Data Analysis

The following material summarizes how the basic data available for this study was reduced and utilized.

(a) All failures and their associated down times reported during the five mission status periods were categorized into appropriate MSFN site equipment areas. The equipment category breakdown list has been presented in previous documents[1] and is not attached to this study.

(b) Mean time between failure (MTBF) estimates, taking down time into account, were calculated via computer programming for each equipment area. Down times for each equipment area were also tabulated.

Failure and down time data for certain equipment areas obtained over all five mission status periods is presented in histogram form in Appendix I. This data is representative of data used in the study.

(c) By interconnecting the equipment areas (or "subsystems") as required for each support function of Figure 1 a functional reliability estimate for a site is obtained from the MTBF estimates of each equipment area and the time interval of site coverage for each mission phase.

An "overall" MTBF estimate for each function is also obtained by combining the estimates for each equipment area. The functional reliability estimates and overall MTBF estimate are not related in a simple exponential way since both series and parallel (redundant) equipment interconnections are involved and the resulting distribution of failure times is no longer exponential. In a redundancy situation for a failure to have occurred, all parallel paths must have failed. Table III presents the basic single site reliability data analysis for each support function. This table gives the single site reliabilities for each support function as calculated from the data for selected time intervals applicable to this study. All subsequent estimates of support reliability are based on Table III.

(d) By considering total MSFN coverage, i.e., the number of sites which can view the spacecraft(s) during any given mission phase, an overall MSFN support function reliability estimate is obtained. In this situation "redundancy" is provided by the number of sites covering. This

[1] For example, the Lunar Orbital Mission Reliability Study included in the October-December 1968, APL quarterly progress report mentioned in the introduction.

Table III

Function	Single Site Reliability of Function Over Time Interval T				
	T = .133 hr	T = 1.0 hr	T = 2.0 hr	T = 8.0 hr	T = 14.0 hr
I	.99893	.99199	.98405	.93758	.89354
A	.99953	.99656	.99313	.97285	.95247
B	.99934	.99452	.98911	.95741	.92645
C	.99967	.99760	.99522	.98105	.96708
D	.99945	.99595	.99192	.96811	.94486
II	.99982	.99882	.99766	.99054	.98321
A	.99984	.99884	.99880	.99083	.98402
B	.99984	.99854	.99769	.99065	.98367
C	.99984	.99854	.99769	.99065	.98367
D	.99984	.99884	.99880	.99083	.98402
E	.99984	.99884	.99769	.99083	.98402
III	.99876	.99080	.98170	.92882	.87877
A	.99983	.99883	.99768	.99081	.98395
B	.99913	.99357	.98717	.94977	.91376
C	.99945	.99593	.99188	.96795	.94459
IV	.99925	.99227	.98462	.93989	.89722
A	.99938	.99542	.99087	.96401	.93788
B	.99942	.99574	.99151	.96648	.93013
C	.99981	.99861	.99723	.98882	.98027
D	.99955	.99660	.99320	.97309	.95338
E	.99975	.99826	.99652	.98608	.97559
F	.99945	.99593	.99188	.96795	.93695
G	.99942	.99574	.99151	.96648	.93013

"redundancy" varies depending upon whether one or two spacecraft are covered. From a reliability standpoint it is found that dual sites provide very little redundancy when a single spacecraft is considered. A summary of site coverage for a lunar mission is given in Figure 2. The detailed information from which the summary of Figure 2 was obtained is included in reference 1. This reference described in detail coverage for a night launch in August 1969 involving translunar injection over the Atlantic. The first lunar landing mission may well occur in July 1969 with translunar injection over the Pacific. These missions would differ in detail as to which sites covered when, but the overall summary of coverage as given in Figure 2 should apply to either.

A summary table of site mode support capability is given in Figure 4. It has been assumed in this study that 30 ft antenna sites can "back up" 85 ft antenna sites at lunar distance in the PM modes. (Contingency" modes or modes other than mode 2 might have to be used.) The 30 ft. antenna sites cannot "back up" the 85 ft. antenna sites at lunar distance in the FM modes which includes television. These assumptions can be inferred from Figure 4. Examples of the variation in equipment redundancy for certain USB areas as a function of site coverage is shown in Figure 3. Implications for other on site equipment existing in the same quantities as those selected for illustration can be obtained from Figure 3.

(e) In estimating "availability" the ratio of average down time to mean time between failure can be used when both the failure times and repair times are exponentially distributed;

$$A \approx 1 - \frac{MTR}{MTBF} + \left(\frac{MTR}{MTBF}\right)^2$$

For this study availability estimates were obtained using average down times for each equipment area but including only those repairs completed within 30 hours in calculating the average down time. The histogram examples of down time data given in Appendix I show a "bi model" or even "multi model" distribution of down times. Much of this is due to "logistics time" during mission status contributing to down times as long as two weeks or so. Such lengthy down times are assumed not to be typical of mission flight periods. It is assumed that every effort would be made during pre launch mission status to provide necessary spares and if needed, replacement could be flown to sites relatively quickly while a mission is in progress.

If "logistics down times" are not considered the data indicates that in most equipment areas most failures are repaired within one day with a typical average down time of about 8 hours.

LUNAR LANDING MISSION REI

Mission phase	Essential data/ major decisions	Duration of single site coverage interval	Required MSFN s
(A) Launch, insertion Earth orbit	(a) Earth orbit determination (b) Translunar injection go/no go	Approximate 8 min on 80 min off ** (typical Earth orbit coverage)	I Determine positi spacecraft versu (tracking/naviga
			II Maintain voice c cation with spac
			III Monitor spacecr and systems
			IV Send commands, up data to space
(B) SIV B Separation, transposition and docking	(a) Lunar landing determination milestone	Approximate 120 min	I Determine posit spacecraft vers (tracking/naviga
			II Maintain voice c cation with spac
			III Monitor spacecr and systems
			IV Send commands up data to spac

*AS DEFINED IN THE MSFN SUPPORT FUNCTION LIST FIG. 1
**DURING "OFF" PERIODS FUNCTION V (MAINTAIN SITE PROFI
***INCLUDES WING SITE

TABLE IV-1

IABILITY NOMINAL OPERATING PARAMETERS FOR MSFN AND SPACECRAFT

upport functions			Given that at least one site capable of supporting the function can be in contact with the spacecraft the minimum number of sites which can be in contact is:			Maximum time interval during which no site capable of supporting the function can be in contact			Single site MTBF estimation for the function					
									One spacecraft S = Single D = Dual			Two spacecraft S = Single D = Dual		
		*	85'	30'	85' or 30'	85'	30'	85' or 30'	30'-S	30'-D	85'	30'-S	30'-D	85'
on of s time tion)	PM rnging doppler angle	A	2***	1	1	25 min	25 min	25 min	318.0	318.0	318.0	318 0	318.0	318.0
		B							171.8	180.4	180.4	171.8	171.3	171.8
		C							400.5	400.5	400.5	400.5	400.5	400.5
		D							240 6	240.6	240.6	240.6	240.6	240.6
ommuni- ecraft	PM modes, VHF	A							740.7	740.7	740.7	740.7	740.7	740.7
		B							467.3	494.1	494.1	467.3	467.3	467.3
		C							436.9	437.3	437.3	436.9	436.9	436.9
		D							740.7	740.7	740.7	740.7	740.7	740.7
		E							716.3	716.3	716.3	716.3	716.3	716.3
	PM modes slow TLM	A							860.9	861.3	861.3	860.9	860.9	860.9
		B							152.7	152.7	152.7	152.7	152.7	152.7
		C							239.4	239.4	239.4	239.4	239.4	239.4
	PM modes normal TLM	A							860.9	861.3	861.3	860.9	860.9	860.9
		B							152.7	152.7	152.7	152.7	152.7	152.7
		C							239.4	239.4	239.4	239.4	239.4	239.4
ift status	FM modes TV	A							860.9	861.3	861.3	860.9	860.9	860.9
		B							152.7	152.7	152.7	152.7	152.7	152.7
		C							239.4	239.4	239.4	239.4	239.4	239.4
	TLM playback	A							860.9	861.3	861.3	860.9	860.9	860.9
		B							152.7	152.7	152.7	152.7	152.7	152.7
		C							239.4	239.4	239.4	239.4	239.4	239.4
	S IV B	A							340.0	340.0	340.0	340.0	340.0	340.0
		B							152.7	152.7	152.7	152.7	152.7	152.7
		C							239.4	239.4	239.4	239.4	239.4	239.4
other craft	PM modes	A							213.4	213.4	213.4	213.4	213.4	213.4
		B							229.0	229.0	213.4	229.0	229.0	229.0
		C							1213.3	1213.8	1213.8	1213.3	1213.3	1213.3
		D							293.3	293.3	293.3	293.3	293.3	293.3
		E							346.3	348.9	348.9	346.3	346.3	346.3
		F							239.4	239.4	239.4	239.4	239.4	239.4
		G	2***	1	1				229.0	229.0	229.0	229.0	229.0	229.0
on of us time ition)	PM rnging doppler angle	A	2***	3	5***				318.0	318.0	318.0	318.0	318.0	318.0
		B							171.8	171.8	171.8	171.8	171.8	171.8
		C							400.5	400.5	400.5	400.5	400.5	400.5
		D							240.6	240.6	240.6	240.6	240.6	240.6
ommuni- ecraft	PM modes, VHF	A							740.7	740.7	740.7	740.7	740.7	740.7
		B							467.3	494.1	494.1	467.3	467.3	467.3
		C							436.9	437.3	437.3	436.9	436.9	436.9
		D							740.7	740.7	740.7	740.7	740.7	740.7
		E							716.3	716.3	716.3	716.3	716.3	716.3
	PM modes slow TLM	A							860.9	861.3	860.9	860.9	860.9	860.9
		B					CONTINUOUS		152.7	152.7	152.7	152.7	152.7	152.7
		C							239.4	239.4	239.4	239.4	239.4	239.4
	PM modes normal TLM	A					COVERAGE		860.9	861.3	861.3	860.9	860.9	860.9
		B							152.7	152.7	152.7	152.7	152.7	152.7
		C							239.4	239.4	239.4	239.4	239.4	239.4
aft status	FM modes TV	A							860.9	861.3	861.3	860.9	860.9	860.9
		B							152.7	152.7	152.7	152.7	152.7	152.7
		C							239.4	239.4	239.4	239.4	239.4	239.4
	TLM playback	A							860.9	861.3	861.3	860.9	860.9	860.9
		B							152.7	152.7	152.7	152.7	152.7	152.7
		C							239.4	239.4	239.4	239.4	239.4	239.4
	S IV B	A							340.0	340.0	340.0	340.0	340.0	340.0
		B							152.7	152.7	152.7	152.7	152.7	152.7
		C							239.4	239.4	239.4	239.4	239.4	239.4
/other craft	PM modes	A							213.4	213.4	213.4	213.4	213.4	213.4
		B							229.0	229.0	229.0	229.0	229.0	229.0
		C							1213.3	1213.3	1213.3	1213.3	1213.3	1213.3
		D							293.3	293.3	293.3	293.3	293.3	293.3
		E							346.3	348.9	348.9	346.3	346.3	346.3
		F							239.4	239.4	239.4	239.4	239.4	239.4
		G							229.0	229.0	229.0	229.0	229.0	229.0

CIENCY) IS ASSUMED TO BE THE REQUIRED SUPPORT FUNCTION

TABLE IV

LUNAR LANDING MISSION RELIABILITY NOMINAL OPERATING

Mission phase	Essential data/ major decisions	Duration of single site coverage interval	Required MSFN support functions		Given that at least one site capable of supporting the function can be in contact with the spacecraft the maximum number of sites which can be in contact is:			
					*	85'	30'	85'
(C) Translunar flight	(a) Abort and return (b) Lunar orbit insertion	Approximate 10 to 14 hrs on 10 to 14 hrs off** (Earths' Diurnal Rotation)	I Determine position of spacecraft versus time (tracking/navigation)	PM rnging doppler angle	A	2***	2	4*
					B			
					C			
					D			
			II Maintain voice communication with spacecraft	PM modes, VHF	A			
					B			
					C			
					D			
					E			
			III Monitor spacecraft status and systems	PM modes slow TLM	A			
					B			
					C			
				PM modes normal TLM	A			
					B			
					C			
				FM modes TV	A			2*
					B			
					C			
				TLM playback	A			
					B			
					C			
				S IV B	A			
					B			
					C			
			IV Send commands/other up data to spacecraft (e.g. transmit navigation updates, transmit midcourse guidance correction targeting, transmit targeting for possible aborts, transmit lunar orbit in section targeting)	PM modes	A		2	4*
					B			
					C			
					D			
					E			
					F			
					G			
(D) Lunar orbit	(a) Lunar orbit determination (b) Lunar module descent & landing (c) Lunar module stay (d) Lunar module ascent & rendezvous	a) Approximately 1.3 hours on, 0.8 hours off for CSM b) Approximately 12 to 14 hours for LM**	I Determine position of spacecraft versus time (tracking/navigation)	PM rnging doppler angle	A	2***	3	5*
					B			
					C			
					D			
			II Maintain voice communication with spacecraft	PM modes, VHF	A			
					B			
					C			
					D			
					E			
			III Monitor spacecraft status and systems (e.g. verify AGC state vector following lunar orbit insertion	PM modes slow TLM	A			
					B			
					C			
				PM modes normal TLM	A			
					B			
					C			
				FM modes TV	A			2*
					B			
					C			
				TLM playback	A			
					B			
					C			
				S IV A	A			
					B			
					C			
			IV Send commands/other up data to a spacecraft (e.g. transmit targeting for lunar orbit insertion 2nd burn, transmit navigation updates, transmit targeting for transearth injection)	PM modes	A		3	5*
					B			
					C			
					D			
					E			
					F			
					G			

*AS DEFINED IN THE MSFN SUPPORT FUNCTION LIST FIG. 1

**DURING "OFF" PERIODS FUNCTION V (MAINTAIN SITE PROFICIENCY) IS ASSUMED TO BE THE REQUIRED S

***INCLUDES WING SITE

TABLE IV-2

NOMINAL OPERATING PARAMETERS FOR MSFN AND SPACECRAFT (cont'd)

Functions		Given that at least one site capable of supporting the function can be in contact with the spacecraft the minimum number of sites which can be in contact is:			Maximum time interval during which no site capable of supporting the function can be in contact			Single site MTBF estimation for the function: One spacecraft S → Single, D → Dual			Single site MTBF estimation for the function: Two spacecraft S → Single, D → Dual		
	*	85'	30'	85' or 30'	85'	30'	85' or 30'	30'–S	30'–D	85'	30'–S	30'–D	85'
PM ranging doppler angle	A	2***	2	4***				318.0	318.0	318.0	318.0	318.0	318.0
	B							171.8	180.4	180.4	171.8	171.8	171.8
	C							400.5	400.5	400.5	400.5	400.5	400.5
	D							240.6	240.6	240.6	240.6	240.6	240.6
PM modes, VHF	A							740.7	740.7	740.7	740.7	740.7	740.7
	B							467.3	494.1	494.1	467.3	467.3	467.3
	C							436.9	437.3	437.3	436.9	436.9	436.9
	D							740.7	740.7	740.7	740.7	740.7	740.7
	E							716.3	716.3	716.3	716.3	716.3	716.3
PM modes slow TLM	A							860.9	861.3	861.3	860.9	860.9	860.9
	B							152.7	152.7	152.7	152.7	152.7	152.7
	C							239.4	239.4	239.4	239.4	239.4	239.4
PM modes normal TLM	A							860.9	861.3	861.3	860.9	860.9	860.9
	B					CONTINUOUS		152.7	152.7	152.7	152.7	152.7	152.7
	C							239.4	239.4	239.4	239.4	239.4	239.4
FM modes TV	A			2***		COVERAGE		860.9	861.3	861.3	860.9	860.9	860.9
	B							152.7	152.7	152.7	152.7	152.7	152.7
	C							239.4	239.4	239.4	239.4	239.4	239.4
TLM playback	A							860.9	861.3	861.3	860.9	860.9	860.9
	B							152.7	152.7	152.7	152.7	152.7	152.7
	C							239.4	239.4	239.4	239.4	239.4	239.4
S IV B	A												
	B												
	C												
PM modes	A		2	4***				213.4	213.4	213.4	213.4	213.4	213.4
	B							229.0	229.0	229.0	229.0	229.0	229.0
	C							1213.3	1213.3	1213.3	1213.3	1213.3	1213.3
	D							293.3	293.3	293.3	293.3	293.3	293.3
	E							346.3	348.9	348.9	346.3	346.3	346.3
	F							239.4	239.4	239.4	239.4	239.4	239.4
	G							229.0	229.0	229.0	229.0	229.0	229.0
PM ranging doppler angle	A	2***	3	5***	48 min (CSM)	48 min (CSM)	48 min (CSM)	318.0	318.0	318.0	318.0	318.0	318.0
	B							171.8	180.4	180.4	171.8	171.8	171.8
	C							400.5	400.5	400.5	400.5	400.5	400.5
	D							240.6	240.6	240.6	240.6	240.6	240.6
PM modes, VHF	A							740.7	740.7	740.7	740.7	740.7	740.7
	B							467.3	494.1	494.1	467.3	467.3	467.3
	C							436.9	437.3	437.3	436.9	436.9	436.9
	D							740.7	740.7	740.7	740.7	740.7	740.7
	E							716.3	716.3	716.3	716.3	716.3	716.3
PM modes slow TLM	A							860.9	861.3	861.3	860.9	860.9	860.9
	B							152.7	152.7	152.7	152.7	152.7	152.7
	C							239.4	239.4	239.4	239.4	239.4	239.4
PM modes normal TLM	A							860.9	861.3	861.3	860.9	860.9	860.9
	B							152.7	152.7	152.7	152.7	152.7	152.7
	C							239.4	239.4	239.4	239.4	239.4	239.4
FM modes TV	A			2***				860.9	861.3	861.3	860.9	860.9	860.9
	B							152.7	152.7	152.7	152.7	152.7	152.7
	C							239.4	239.4	239.4	239.4	239.4	239.4
TLM playback	A							860.9	861.3	861.3	860.9	860.9	860.9
	B							152.7	152.7	152.7	152.7	152.7	152.7
	C							239.4	239.4	239.4	239.4	239.4	239.4
S IV A	A												
	B												
	C												
PM modes	A		3	5***				213.4	213.4	213.4	213.4	213.4	213.4
	B							226.0	226.0	226.0	226.0	226.0	226.0
	C							1213.3	1213.3	1213.3	1213.3	1213.3	1213.3
	D							293.3	293.3	293.3	293.3	293.3	293.3
	E							346.3	348.9	348.9	346.3	346.3	346.3
	F							239.4	239.4	239.4	239.4	239.4	239.4
	G							229.0	229.0	229.0	229.0	229.0	229.0

* IS ASSUMED TO BE THE REQUIRED SUPPORT FUNCTION

TABLE IV-

LUNAR LANDING MISSION RELIABILITY NOMINAL OPERATING

Mission phase	Essential data major decisions	Duration of single site coverage interval	Required MSFN support functions		Given that at least one site capable of supporting the function can be in contact with the spacecraft the minimum number of sites which can be in contact is:			
					*	85'	30'	85' or 30'
(E) Transearth flight	(a) Transearth injection (b) Earths' atmosphere entry	Approximate 10 to 14 hrs on 10 to 14 hrs off**	I Determine position of spacecraft versus time (tracking navigation)	PM rnging doppler angle	A B C D	2***	2	4***
			II Maintain voice communication with spacecraft	PM modes, VHF	A B C D E			
			III Monitor spacecraft status and systems (e.g. verify AGC state vector following trans-earth injection)	PM modes slow TLM	A B C			
				PM modes normal TLM	A B C			
				FM modes TV	A B C			2***
				TLM playback	A B C			
				S IV B	A B C			
			IV Send commands other up data to spacecraft (e.g. transmit targeting for entry corridor control)	PM modes	A B C D E F G		2	4***
(F) Entry		Approximate 10 minutes	I Determine position of spacecraft versus time (tracking/navigation) (e.g. entry trajectory monitoring, splash point prediction)	PM rnging doppler angle	A B C D		1	1
			II Maintain voice communication with spacecraft	PM modes, VHF	A B C D E			
				PM modes slow TLM	A B C			
				PM modes normal TLM	A B C			
			III Monitor spacecraft status and systems	FM modes TV	A B C			
				TLM playback	A B C			
				S IV A	A B C			
			IV Send commands/other up data to spacecraft	PM modes	A B C D E F G			

*AS DEFINED IN THE MSFN SUPPORT FUNCTION LIST FIG. 1

**DURING "OFF" PERIODS FUNCTION V (MAINTAIN SITE PROFICIENCY) IS ASSUMED TO BE THE REQUIRED SUPP

***INCLUDES WING SITE

TABLE IV-3

BILITY NOMINAL OPERATING PARAMETERS FOR MSFN AND SPACECRAFT (cont'd)

upport functions			Given that at least one site capable of supporting the function can be in contact with the spacecraft the minimum number of sites which can be in contact is:			Maximum time interval during which no site capable of supporting the function can be in contact			Single site MTBF estimation for the function					
									One spacecraft S = Single D = Dual			Two spacecraft S = Single D = Dual		
		*	85'	30'	85' or 30'	85'	30'	85' or 30'	30'-S	30'-D	85'	30'-S	30'-D	85'
n of us time ation)	PM ranging doppler angle	A	2***	2	4***				318.0	318.0	318.0	318.0	318.0	318.0
		B							171.8	180.4	180.4	171.8	171.8	171.8
		C							400.5	400.5	400.5	400.5	420.5	400.5
		D							240.6	240.6	240.6	240.6	240.6	240.6
ommuni- ecraft	PM modes, VHF	A							740.7	740.7	740.7	740.7	740.7	740.7
		B							467.3	494.1	494.1	467.3	467.3	467.3
		C							436.9	437.3	437.3	436.9	436.9	436.9
		D							740.7	740.7	740.7	740.7	740.7	740.7
		E							716.3	716.3	716.3	716.3	716.3	716.3
aft status state , trans-	PM modes slow TLM	A							860.9	861.3	861.3	860.9	860.9	860.9
		B							152.7	152.7	152.7	152.7	152.7	152.7
		C							239.4	239.4	239.4	239.4	239.4	239.4
	PM modes normal TLM	A							860.9	861.3	861.3	860.9	860.9	860.9
		B					CONTINUOUS		152.7	152.7	152.7	152.7	152.7	152.7
		C							239.4	239.4	239.4	239.4	239.4	239.4
	PM modes TV	A			2***		COVERAGE		860.9	861.3	861.3	860.9	860.9	860.9
		B							152.7	152.7	152.7	152.7	152.7	152.7
		C							239.4	239.4	239.4	239.4	239.4	239.4
	TLM playback	A							860.9	861.3	861.3	860.9	860.9	860.9
		B							152.7	152.7	152.7	152.7	152.7	152.7
		C							239.4	239.4	239.4	239.4	239.4	239.4
	S IV B	A												
		B												
		C												
other up aft rgeting r	PM modes	A		2	4***				213.4	213.4	213.4	213.4	213.4	213.4
		B							229.0	229.0	229.0	229.0	229.0	229.0
		C							1213.3	1213.3	1213.3	1213.3	1213.3	1213.3
		D							293.3	293.3	293.3	293.3	293.3	293.3
		E							346.3	348.9	348.9	346.3	346.3	346.3
		F							239.4	239.4	239.4	239.4	239.4	239.4
		G							229.0	229.0	229.0	229.0	229.0	229.0
ion of us time ation) ectory ush point	PM ranging doppler angle	A		1	1		3 min	3 min	318.0	318.0	310.0	318.0	318.0	318.0
		B							171.8	180.4	180.4	171.8	171.8	171.8
		C							400.5	400.5	400.5	400.5	400.5	400.5
		D							240.6	240.6	240.6	240.6	240.6	240.6
ommuni- cecraft	PM modes, VHF	A							740.7	740.7	740.7	740.7	740.7	740.7
		B							467.3	494.1	494.1	467.3	467.3	467.3
		C							436.9	437.3	437.3	436.9	436.9	436.9
		D							740.7	740.7	740.7	740.7	740.7	740.7
		E							716.3	716.3	716.3	716.3	716.3	716.3
aft status	PM modes slow TLM	A							860.9	861.3	861.3	860.9	860.9	860.9
		B							152.7	152.7	152.7	152.7	152.7	152.7
		C							239.4	239.4	239.4	239.4	239.4	239.4
	PM modes normal TLM	A							860.9	861.3	861.3	860.9	860.9	860.9
		B							152.7	152.7	152.7	152.7	152.7	152.7
		C							239.4	239.4	239.4	239.4	239.4	239.4
	FM modes TV	A							860.9	861.3	861.3	860.9	860.9	860.9
		B							152.7	152.7	152.7	152.7	152.7	152.7
		C							239.4	239.4	239.4	239.4	239.4	239.4
	TLM playback	A							860.9	861.3	861.3	860.9	860.9	860.9
		B							152.7	152.7	152.7	152.7	152.7	152.7
		C							239.4	239.4	239.4	239.4	239.4	239.4
	S IV A	A												
		B												
		C												
other ecraft	PM modes	A							213.4	213.4	213.4	213.4	213.4	213.4
		B							229.0	229.0	229.0	229.0	229.0	229.0
		C							1213.3	1213.3	1213.5	1213.3	1213.3	1213.3
		D							293.3	293.3	293.3	293.3	293.3	293.3
		E							346.3	348.9	348.9	346.3	346.3	346.3
		F							239.4	239.4	239.4	239.4	239.4	239.4
		G							229.0	229.0	229.0	229.0	229.0	229.0

CIENCY) IS ASSUMED TO BE THE REQUIRED SUPPORT FUNCTION

TABLE IV-4

LUNAR LANDING MISSION RELIABILITY NOMINAL OPERATING PARAMETERS FOR

Mission phase	Essential data/ major decisions	Duration of single site coverage interval	Required MSFN support functions		Single site over the cove			
					One spacecraft S – Single D – Dual			
					*	30'–S	30'–D	85'
(A) Launch, insertion, Earth orbit	(a) Earth orbit determination (b) Translunar injection go/no go	Approximate 8 min on 80 min off** (typical Earth orbit coverage)	I Determine position of spacecraft versus time (tracking/navigation)	PM rnging doppler angle	A	.99953	.99953	.9995
					B	.99934	.99934	.9993
					C	.99967	.99967	.9996
					D	.99945	.99945	.9994
			II Maintain voice communication with spacecraft	PM modes, VHF	A	.99984	.99984	.9998
					B	.99984		
					C	.99984		
					D	.99984		
					E	.99984		
			III Monitor spacecraft status and systems	PM modes slow TLM	A	.99983	.99983	.9998
					B	.99913	.99913	.9991
					C	.99945	.99945	.9994
				PM modes normal TLM	A	.99983	.99983	.9998
					B	.99913	.99913	.9991
					C	.99945	.99945	.9994
				FM modes TV	A	.99983	.99983	.9998
					B	.99913	.99913	.9991
					C	.99945	.99945	.9994
				TLM playback	A	.99983	.99983	.9998
					B	.99913	.99913	.9991
					C	.99945	.99945	.9994
				S IV B	A	.99960	.99960	.9996
					B	.99913	.99913	.9991
					C	.99945	.99945	.9994
			IV Send commands/other up data to spacecraft	PM modes	A	.99938	.99938	.9993
					B	.99942	.99942	.9994
					C	.99981	.99981	.9998
					D	.99955	.99955	.9995
					E	.99975	.99975	.9997
					F	.99945	.99945	.9994
					G	.99942	.99942	.999
(B) SIV B Separation, transposition and docking	(a) Lunar landing determination milestone	Approximate 120 min	I Determine position of spacecraft versus time (tracking/navigation)	PM rnging doppler angle	A	.99313	.99313	.993
					B	.98911	.98911	.989
					C	.99522	.99522	.995
					D	.99192	.99192	.991
			II Maintain voice communication with spacecraft	PM modes, VHF	A	.99880	.99880	.998
					B	.99769	.99769	.997
					C	.99769	.99769	.997
					D	.99880	.99880	.998
					E	.99769	.99769	.997
			III Monitor spacecraft status and systems	PM modes slow TLM	A	.99768	.99768	.997
					B	.98717	.98717	.987
					C	.99188	.99188	.991
				PM modes normal TLM	A	.99769	.99769	.997
					B	.98717	.98717	.987
					C	.99188	.99188	.991
				FM modes TV	A	.99769	.99769	.997
					B	.98717	.98717	.987
					C	.99188	.99188	.991
				TLM playback	A	.99769	.99769	.997
					B	.98717	.98717	.987
					C	.99188	.99188	.991
				S IV B	A	.99404	.99404	.994
					B	.98717	.98717	.987
					C	.99188	.99188	.991
			IV Send commands/other up data to spacecraft	PM modes	A	.99087	.99087	.990
					B	.99151	.99151	.991
					C	.99273	.99273	.992
					D	.99320	.99320	.993
					E	.99652	.99652	.996
					F	.99188	.99188	.99
					G	.99151	.99151	.991

*AS DEFINED IN THE MSFN SUPPORT FUNCTION LIST FIG. 1

**DURING "OFF" PERIODS FUNCTION V (MAINTAIN SITE PROFICIENCY) IS ASSUMED TO BE THE REQUIRED SUPPORT FUNCTION.

TABLE IV-4

...ABILITY NOMINAL OPERATING PARAMETERS FOR MSFN AND SPACECRAFT (cont'd)

...ation of ...gle site ...ge interval	Required MSFN support functions		*	Single site reliability over the coverage interval: One spacecraft (S – Single, D – Dual) 30'–S	30'–D	85'	Two spacecraft (S – Single, D – Dual) 30'–S	30'–D	85'	Overall reliability over the coverage interval (multiple sites): One spacecraft	Two spacecraft
...imate ...n ...off** ...l Earth ...overage)	I Determine position of spacecraft versus time (tracking/navigation)	PM rnging doppler angle	A	.99953	.99953	.99953	.99953	.99953	.999953	.999953	
			B	.99934	.99934	.99934	.99934	.99934	.99934	.99934	
			C	.99967	.99967	.99967	.99967	.99967	.99967	.99967	
			D	.99945	.99945	.99945	.99945	.99945	.99945	.99945	
	II Maintain voice communication with spacecraft	PM modes, VHF	A	.99984	.99984	.99984	.99984	.99984	.99984	.99984	
			B	.99984							
			C	.99984							
			D	.99984							
			E	.99984							
	III Monitor spacecraft status and systems	PM modes slow TLM	A	.99983	.99983	.99983	.99983	.99983	.99983	.99983	
			B	.99913	.99913	.99913	.99913	.99913	.99913	.99913	
			C	.99945	.99945	.99945	.99945	.99945	.99945	.99945	
		PM modes normal TLM	A	.99983	.99983	.99983	.99983	.99983	.99983	.99983	
			B	.99913	.99913	.99913	.99913	.99913	.99913	.99913	
			C	.99945	.99945	.99945	.99945	.99945	.99945	.99945	
		FM modes TV	A	.99983	.99983	.99983	.99983	.99983	.99983	.99983	
			B	.99913	.99913	.99913	.99913	.99913	.99913	.99913	
			C	.99945	.99945	.99945	.99945	.99945	.99945	.99945	
		TLM playback	A	.99983	.99983	.99983	.99983	.99983	.99983	.99983	
			B	.99913	.99913	.99913	.99913	.99913	.99913	.99913	
			C	.99945	.99945	.99945	.99945	.99945	.99945	.99945	
		S IV B	A	.99960	.99960	.99960	.99960	.99960	.99960	.99960	
			B	.99913	.99913	.99913	.99913	.99913	.99913	.99913	
			C	.99945	.99945	.99945	.99945	.99945	.99945	.99945	
	IV Send commands/other up data to spacecraft	PM modes	A	.99938	.99938	.99938	.99938	.99938	.99938	.99938	
			B	.99942	.99942	.99942	.99942	.99942	.99942	.99942	
			C	.99981	.99981	.99981	.99981	.99981	.99981	.99981	
			D	.99955	.99955	.99955	.99955	.99955	.99955	.99955	
			E	.99975	.99975	.99975	.99975	.99975	.99975	.99975	
			F	.99945	.99945	.99945	.99945	.99945	.99945	.99945	
			G	.99942	.99942	.99942	.99942	.99942	.99942	.99942	
...ximate ...in	I Determine position of spacecraft versus time (tracking/navigation)	PM rnging doppler angle	A	.99313	.99313	.99313	.99313	.99313	.99313	.999999+	.99995
			B	.98911	.98911	.98911	.98911	.98911	.98911		.99987
			C	.99522	.99522	.99522	.99522	.99522	.99522		.99998
			D	.99192	.99192	.99192	.99192	.99192	.99192		.99993
	II Maintain voice communication with spacecraft	PM modes, VHF	A	.99880	.99880	.99880	.99880	.99880	.99880		.99999+
			B	.99769	.99769	.99769	.99769	.99769	.99769		.99999
			C	.99769	.99769	.99769	.99769	.99769	.99769		.99999
			D	.99880	.99880	.99880	.99880	.99880	.99880		.99999+
			E	.99769	.99769	.99769	.99769	.99769	.99769		.99999
	III Monitor spacecraft status and systems	PM modes slow TLM	A	.99768	.99768	.99768	.99768	.99768	.99768		.99999
			B	.98717	.98717	.98717	.98717	.98717	.98717		.99984
			C	.99188	.99188	.99188	.99188	.99188	.99188		.99993
		PM modes normal TLM	A	.99769	.99769	.99769	.99769	.99769	.99769		.99999
			B	.98717	.98717	.98717	.98717	.98717	.98717		.99984
			C	.99188	.99188	.99188	.99188	.99188	.99188		.99993
		FM modes TV	A	.99769	.99769	.99769	.99769	.99769	.99769		.99999
			B	.98717	.98717	.98717	.98717	.98717	.98717		.99984
			C	.99188	.99188	.99188	.99188	.99188	.99188		.99993
		TLM playback	A	.99769	.99769	.99769	.99769	.99769	.99769		.99999
			B	.98717	.98717	.98717	.98717	.98717	.98717		.99984
			C	.99188	.99188	.99188	.99188	.99188	.99188		.99993
		S IV B	A	.99404	.99404	.99404	.99404	.99404	.99404	.999989	.99996
			B	.98717	.98717	.98717	.98717	.98717	.98717	.999999+	.99984
			C	.99188	.99188	.99188	.99188	.99188	.99188		.99993
	IV Send commands/other up data to spacecraft	PM modes	A	.99087	.99087	.99087	.99087	.99087	.99087		.99992
			B	.99151	.99151	.99151	.99151	.99151	.99151		.99993
			C	.99273	.99273	.99273	.99273	.99273	.99273		.99999
			D	.99320	.99320	.99320	.99320	.99320	.99320		.99995
			E	.99652	.99652	.99652	.99652	.99652	.99652		.99995
			F	.99188	.99188	.99188	.99188	.99188	.99188		.99999
			G	.99151	.99151	.99151	.99151	.99151	.99151		.99793

...T FIG. 1

...TE PROFICIENCY) IS ASSUMED TO BE THE REQUIRED SUPPORT FUNCTION.

TABLE IV-5
LUNAR LANDING MISSION RELIABILITY NOMINAL OPERATING PARAMETERS FO[R]

Mission phase	Essential data/ major decisions	Duration of single site coverage interval	Required MSFN support functions		Single site r[eliability] over the cov[erage interval]: One spacecraft, S – Single, D – Dual: *	30'–S	30'–D	85'
(C) Translunar flight	(a) Abort and return (b) Lunar orbit insertion	Approximate 10 to 14 hrs on 10 to 14 hrs off** (Earths' Diurnal Rotation)	I Determine position of spacecraft versus time (tracking/navigation)	PM rnging doppler angle	A	.95247	.95247	.95247
					B	.92645	.92645	.92645
					C	.96708	.96708	.96708
					D	.94486	.94486	.9448
			II Maintain voice communication with spacecraft	PM modes, VHF	A	.98402	.98402	.98402
					B	.98367	.98367	.98367
					C	.98347	.98347	.98347
					D	.98402	.98402	.98402
					E	.98402	.98402	.98402
			III Monitor spacecraft status and systems	PM modes slow TLM	A	.98395	.98395	.98395
					B	.91376	.91376	.9137
					C	.94459	.94459	.9445
				PM modes normal TLM	A	.98395	.98395	.98395
					B	.91376	.91376	.91376
					C	.94459	.94459	.94459
				FM modes TV	A			.98395
					B			.9137
					C			.9445
				TLM playback	A			.9839
					B			.9137
					C			.9445
				S IV B	A			
					B			
					C			
			IV Send commands/other up data to spacecraft (e.g. transmit navigation updates, transmit midcourse guidance correction targeting, transmit targeting for possible aborts, transmit lunar orbit in section targeting)	PM modes	A	.93788	.93788	.9378
					B	.93013	.93013	.9301
					C	.98027	.98027	.9802
					D	.95338	.95338	.9533
					E	.97559	.97559	.9755
					F	.93695	.93695	.9369
					G	.93013	.93013	.9301
(D) Lunar orbit	(a) Lunar orbit determination (b) Lunar module descent & landing (c) Lunar module stay (d) Lunar module ascent & rendezvous	a) Approximately 1.3 hours on, 0.8 hours off for CSM b) Approximately 12 to 14 hours for LM**	I Determine position of spacecraft versus time (tracking/navigation)	PM rnging doppler angle	A	.95247	.95247	.9524
					B	.92645	.92645	.9264
					C	.96708	.96708	.9670
					D	.94486	.94486	.9448
			II Maintain voice communication with spacecraft	PM modes, VHF	A	.98402	.98402	.9840
					B	.98367	.98367	.9836
					C	.98347	.98347	.9834
					D	.98402	.98402	.9840
					E	.98402	.98402	.9840
			III Monitor spacecraft status and systems (e.g. verify AGC state vector following lunar orbit insertion)	PM modes slow TLM	A	.98395	.98395	.9839
					B	.91376	.91376	.9137
					C	.94459	.94459	.9445
				PM modes normal TLM	A	.98395	.98395	.9839
					B	.91376	.91376	.9137
					C	.94459	.94459	.9445
				FM modes TV	A			.9839
					B			.9137
					C			.9445
				TLM playback	A			.9839
					B			.9137
					C			.9445
				S IV B	A			
					B			
					C			
			IV Send commands/other up data to spacecraft (e.g. transmit targeting for lunar orbit insertion 2nd burn, transmit navigation updates, transmit targeting for transearth injection)	PM modes	A	.93788	.93788	.9378
					B	.93013	.93013	.9301
					C	.98027	.98027	.9802
					D	.95338	.95338	.9533
					E	.97559	.97559	.9755
					F	.93695	.93695	.9369
					G	.93013	.93013	.9301

*AS DEFINED IN THE MSFN SUPPORT FUNCTION LIST FIG.1
**DURING "OFF" PERIODS FUNCTION V (MAINTAIN SITE PROFICIENCY) IS ASSUMED TO BE THE REQUIRED SUPPORT FUNCTION.

TABLE IV-5
LITY NOMINAL OPERATING PARAMETERS FOR MSFN AND SPACECRAFT (cont'd)

val	Required MSFN support functions			Single site reliability over the coverage interval: One spacecraft (S – Single, D – Dual) 30'–S	30'–D	85'	Two spacecraft (S – Single, D – Dual) 30'–S	30'–D	85'	Overall reliability over the coverage interval (multiple sites): One spacecraft	Two spacecraft
n	I Determine position of spacecraft versus time (tracking/navigation)	PM rnging doppler angle	A	.95247	.95247	.95247	.95247	.95247	.95247	.999999	.99891
ff**			B	.92645	.92645	.92645	.92645	.92645	.92645	.999995	.99883
al			C	.96708	.96708	.96708	.96708	.96708	.96708	.999999+	.99980
			D	.94486	.94486	.94486	.94486	.94486	.94486	.999998	.99939
	II Maintain voice communication with spacecraft	PM modes, VHF	A	.98402	.98402	.98402	.98402	.98402	.98402	.999999+	.99995
			B	.98367	.98367	.98367	.98367	.98367	.98367		
			C	.98347	.98347	.98347	.98347	.98347	.98347		
			D	.98402	.98402	.98402	.98402	.98402	.98402		
			E	.98402	.98402	.98402	.98402	.98402	.98402		
	III Monitor spacecraft status and systems	PM modes slow TLM	A	.98395	.98395	.98395	.98395	.98395	.98395	.999999+	.99995
			B	.91376	.91376	.91376	.91376	.91376	.91376	.999990	.99833
			C	.94459	.94459	.94459	.94459	.94459	.94459	.999998	.99937
		PM modes normal TLM	A	.98395	.98395	.98395	.98395	.98395	.98395	.999999+	.99995
			B	.91376	.91376	.91376	.91376	.91376	.91376	.999990	.99833
			C	.94459	.94459	.94459	.94459	.94459	.94459	.999998	.99937
		FM modes TV	A			.98395			.98395	.99978	.98619
			B			.91376			.91376	.99342	.92689
			C			.94459			.94459	.99744	.95338
		TLM playback	A			.98395			.98395	.99978	.98619
			B			.91376			.91376	.99342	.92689
			C			.94459			.94459	.99744	.95338
		SIVB	A								
			B								
			C								
	IV Send commands/other up data to spacecraft (e.g. transmit navigation updates, transmit midcourse guidance correction targeting, transmit targeting for possible aborts, transmit lunar orbit in section targeting)	PM modes	A	.93788	.93788	.93788	.93788	.93788	.93788	.999997	.99920
			B	.93013	.93013	.93013	.93013	.93013	.93013	.999996	.99896
			C	.98027	.98027	.98027	.98027	.98027	.98027	.999999+	.99993
			D	.95338	.95338	.95338	.95338	.95338	.95338	.999999	.99957
			E	.97559	.97559	.97559	.97559	.97559	.97559	.999999+	.99989
			F	.93695	.93695	.93695	.93695	.93695	.93695	.999999+	.99917
			G	.93013	.93013	.93013	.93013	.93013	.93013	.999996	.99896
tely	I Determine position of spacecraft versus time (tracking/navigation)	PM rnging doppler angle	A	.95247	.95247	.95247	.95247	.95247	.95247	.999999	.99891
n,			B	.92645	.92645	.92645	.92645	.92645	.92645	.999995	.99833
ff			C	.96708	.96708	.96708	.96708	.96708	.96708	.999999+	.99980
			D	.94486	.94486	.94486	.94486	.94486	.94486	.999998	.99939
	II Maintain voice communication with spacecraft	PM modes, VHF	A	.98402	.98402	.98402	.98402	.98402	.98402	.999999+	.99995
tely			B	.98367	.98367	.98367	.98367	.98367	.98367		
ours			C	.98347	.98347	.98347	.98347	.98347	.98347		
			D	.98402	.98402	.98402	.98402	.98402	.98402		
			E	.98402	.98402	.98402	.98402	.98402	.98402		
	III Monitor spacecraft status and systems (e.g. verify AGC state vector following lunar orbit insertion)	PM modes slow TLM	A	.98395	.98395	.98395	.98395	.98395	.98395	.999999+	.99995
			B	.91376	.91376	.91376	.91376	.91376	.91376	.999990	.99833
			C	.94459	.94459	.94459	.94459	.94459	.94459	.999998	.99937
		PM modes normal TLM	A	.98395	.98395	.98395	.98395	.98395	.98395	.999999+	.99995
			B	.91376	.91376	.91376	.91376	.91376	.91376	.999990	.99833
			C	.94459	.94459	.94459	.94459	.94459	.94459	.999998	.99937
		FM modes TV	A			.98395			.98395	.99978	.98619
			B			.91376			.91376	.99342	.92689
			C			.94459			.94459	.99744	.95338
		TLM playback	A			.98395			.98395	.99978	.98619
			B			.91376			.91376	.99342	.92639
			C			.94459			.94459	.99744	.95388
		SIVB	A								
			B								
			C								
	IV Send commands/other up data to spacecraft (e.g. transmit targeting for lunar orbit insertion 2nd burn, transmit navigation updates, transmit targeting for transearth injection)	PM modes	A	.93788	.93788	.93788	.93788	.93788	.93788	.999997	.99920
			B	.93013	.93013	.93013	.93013	.93013	.93013	.999996	.99896
			C	.98027	.98027	.98027	.98027	.98027	.98027	.999999+	.99993
			D	.95338	.95338	.95338	.95338	.95338	.95338	.999999	.99957
			E	.97559	.97559	.97559	.97559	.97559	.97559	.999999+	.99989
			F	.93695	.93695	.93695	.93695	.93695	.93695	.999999+	.99917
			G	.93013	.93013	.93013	.93013	.93013	.93013	.999996	.99896

OFICIENCY) IS ASSUMED TO BE THE REQUIRED SUPPORT FUNCTION.

TABLE IV-6

LUNAR LANDING MISSION RELIABILITY NOMINAL OPERATING PARAMETERS FOR MSFN A

Mission phase	Essential data/ major decisions	Duration of single site coverage interval	Required MSFN support functions		*	Single site reliability over the coverage interval: One spacecraft (S – Single, D – Dual) 30'–S	30'–D	85'	Two spacecraft 30'–S	30'–
(E) Transearth flight	(a) Transearth injection (b) Earths' atmosphere entry	Approximate 10 to 14 hrs on 10 to 14 hrs off**	I Determine position of spacecraft versus time (tracking/navigation)	PM rnging doppler angle	A	.95247	.95247	.95247		
					B	.92645	.92645	.92645		
					C	.96708	.96708	.96708		
					D	.94486	.94486	.94486		
			II Maintain voice communication with spacecraft	PM modes, VHF	A	.98402	.98402	.98402		
					B	.98367	.98367	.98367		
					C	.98347	.98347	.98347		
					D	.98402	.98402	.98402		
					E	.98402	.98402	.98402		
			III Monitor spacecraft status and systems (e.g. verify AGC state vector following transearth injection)	PM modes slow TLM	A	.98395	.98395	.98395		
					B	.91376	.91376	.91376		
					C	.94459	.94459	.94459		
				PM modes normal TLM	A	.98395	.98395	.98395		
					B	.91376	.91376	.91376		
					C	.94459	.94459	.94459		
				FM modes TV	A			.98395		
					B			.91376		
					C			.94459		
				TLM playback	A			.98395		
					B			.91376		
					C			.94459		
				S IV B	A					
					B					
					C					
			IV Send commands/other up data to spacecraft (e.g. transmit targeting for entry corridor control)	PM modes	A	.93788	.93788	.93788		
					B	.93013	.93013	.93013		
					C	.98027	.98027	.98027		
					D	.95338	.95338	.95338		
					E	.97559	.97559	.97559		
					F	.93695	.93695	.93695		
					G	.93013	.93013	.93013		
(F) Entry		Approximate 10 minutes	I Determine position of spacecraft versus time (tracking/navigation) (e.g. entry trajectory monitoring, splash point prediction)	PM rnging doppler angle	A	.99953	.99953	.99953		
					B	.99934	.99934	.99934		
					C	.99967	.99967	.99967		
					D	.99945	.99945	.99945		
			II Maintain voice communication with spacecraft	PM modes, VHF	A	.99984	.99984	.99984		
					B					
					C					
					D					
					E					
			III Monitor spacecraft status and systems	PM modes slow TLM	A	.99983	.99983	.99983		
					B	.99913	.99913	.99913		
					C	.99945	.99945	.99945		
				PM modes normal TLM	A	.99983	.99983	.99983		
					B	.99913	.99913	.99913		
					C	.99945	.99945	.99945		
				FM modes TV	A	.99983	.99983	.99983		
					B	.99913	.99913	.99913		
					C	.99945	.99945	.99945		
				TLM playback	A	.99983	.99983	.99983		
					B	.99913	.99913	.99913		
					C	.99945	.99945	.99945		
				S IV B	A					
					B					
					C					
			IV Send commands/other up data to spacecraft	PM modes	A	.99938	.99938	.99938		
					B	.99942	.99942	.99942		
					C	.99981	.99981	.99981		
					D	.99955	.99955	.99955		
					E	.99975	.99975	.99975		
					F	.99945	.99945	.99945		
					G	.99942	.99942	.99942		

*AS DEFINED IN THE MSFN SUPPORT FUNCTION LIST FIG. 1

**DURING "OFF" PERIODS FUNCTION V (MAINTAIN SITE PROFICIENCY) IS ASSUMED TO BE THE REQUIRED SUPPORT FUNCTION.

TABLE IV-6

...IABILITY NOMINAL OPERATING PARAMETERS FOR MSFN AND SPACECRAFT (cont'd)

...ation of ...gle site ...ge interval	Required MSFN support functions		*	Single site reliability over the coverage interval: One spacecraft (S – Single, D – Dual) 30'–S	30'–D	85'	Two spacecraft (S – Single, D – Dual) 30'–S	30'–D	85'	Overall reliability over the coverage interval (multiple sites): One space-craft	Two space-craft
...ximate ...4 hrs on ...4 hrs off**	I Determine position of spacecraft versus time (tracking/navigation)	PM ranging doppler angle	A	.95247	.95247	.95247				.999999	
			B	.92645	.92645	.92645				.999995	
			C	.96708	.96708	.96708				.999999+	
			D	.94486	.94486	.94486				.999998	
	II Maintain voice communication with spacecraft	PM modes, VHF	A	.98402	.98402	.98402				.999999+	
			B	.98367	.98367	.98367					
			C	.98347	.98347	.98347					
			D	.98402	.98402	.98402					
			E	.98402	.98402	.98402					
	III Monitor spacecraft status and systems (e.g. verify AGC state vector following transearth injection)	PM modes slow TLM	A	.98395	.98395	.98395				.999999+	
			B	.91376	.91376	.91376				.999990	
			C	.94459	.94459	.94459				.999998	
		PM modes normal TLM	A	.98395	.98395	.98395				.999999+	
			B	.91376	.91376	.91376				.999990	
			C	.94459	.94459	.94459				.999998	
		FM modes TV	A			.98395				.99978	
			B			.91376				.99342	
			C			.94459				.99744	
		TLM playback	A			.98395				.99978	
			B			.91376				.99342	
			C			.94459				.99744	
		S IV B	A								
			B								
			C								
	IV Send commands/other up data to spacecraft (e.g. transmit targeting for entry corridor control)	PM modes	A	.93788	.93788	.93788				.999997	
			B	.93013	.93013	.93013				.999996	
			C	.98027	.98027	.98027				.999999+	
			D	.95338	.95338	.95338				.999999	
			E	.97559	.97559	.97559				.999999+	
			F	.93695	.93695	.93695				.999999+	
			G	.93013	.93013	.93013				.999996	
...ximate ...nutes	I Determine position of spacecraft versus time (tracking/navigation) (e.g. entry trajectory monitoring, splash point prediction)	PM ranging doppler angle	A	.99953	.99953	.99953				.99953	
			B	.99934	.99934	.99934				.99934	
			C	.99967	.99967	.99967				.99967	
			D	.99945	.99945	.99945				.99945	
	II Maintain voice communication with spacecraft	PM modes, VHF	A	.99984	.99984	.99984				.99984	
			B								
			C								
			D								
			E	.99983	.99983	.99983				.99983	
	III Monitor spacecraft status and systems	PM modes slow TLM	A	.99983	.99983	.99983				.99983	
			B	.99913	.99913	.99913				.99913	
			C	.99945	.99945	.99945				.99945	
		PM modes normal TLM	A	.99983	.99983	.99983				.99983	
			B	.99913	.99913	.99913				.99913	
			C	.99945	.99945	.99945				.99945	
		FM modes TV	A	.99983	.99983	.99983				.99983	
			B	.99913	.99913	.99913				.99913	
			C	.99945	.99945	.99945				.99945	
		TLM playback	A	.99983	99983	.99983				.99983	
			B	.99913	.99913	.99913				.99913	
			C	.99945	.99945	.99945				.99945	
		S IV B	A								
			B								
			C								
	IV Send commands/other up data to spacecraft	PM modes	A	.99938	.99938	.99938				.99938	
			B	.99942	.99942	.99942				.99942	
			C	.99981	.99981	.99981				.99981	
			D	.99955	.99955	.99955				.99955	
			E	.99975	.99975	.99975				.99975	
			F	.99945	.99945	.99945				.99945	
			G	.99942	.99942	.99942				.99942	

...N LIST FIG. 1

...AIN SITE PROFICIENCY) IS ASSUMED TO BE THE REQUIRED SUPPORT FUNCTION.

1.) Launch, Earth Parking Orbit
   a) Coverage (Discontinuous)
      Minimum number of sites, one, 85 ft or 30 ft antenna
      Typical number of sites, two or more in certain regions
   b) Typical time interval of coverage by one site, 8 minutes

2.) Translunar Injection (TLI)
   a) Coverage (Continuous)
      Minimum number of sites, two 30 ft antenna dual sites, (one a ship)
      Typical number of sites after TLI, one 85 ft site and wing site, three 30 ft antenna dual sites (one a ship)
   b) Typical time interval of coverage by one site, TLI approx. 5 minutes, 9 hours following TLI

3.) Transposition and Docking, S4-B Separation (T and D)
   a) Coverage (Continuous)
      Minimum number of sites, one 85 ft antenna site with wing site, three 30 ft antenna dual sites (one a ship)
      Typical number of sites, same as above for about 4 hours after transposition and docking, then additional coverage available
   b) Typical time interval of coverage by one site, T and D approx. 2 hours, 7 hours following T and D

4.) Translunar Flight
   a) Coverage (Continuous)
      Minimum number of sites, one 85 ft antenna site and wing site, two 30 ft antenna dual sites
      Typical number of sites, one 85 ft antenna site and wing site, two 30 ft antenna dual sites, and two 30 ft antenna single sites
      Maximum number of sites, two 85 ft antenna sites and wing sites, two 30 ft antenna dual sites, and six 30 ft antenna single sites
   b) Typical time interval of coverage by one site, 12 hours
      (Over a 12 hour interval the continuous coverage will be by the minimum number of sites for approximately 2 hours, the typical number for approximately 8 hours, and the maximum number for approximately 2 hours)

Figure 2—Approximate Summary of MSFN Coverage for a Lunar Mission

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5.) Prior to Lunar Orbit Insertion
- a) Coverage (Continuous)
  Typical number of sites, one 85 ft antenna site with wing site, three 30 ft antenna dual sites
- b) Typical time interval of coverage by one site, 3 to 9 hours prior to lunar occultation

6.) Lunar Orbit by CSM, Lunar Stay by LM
- a) Coverage (Continuous for LM, discontinuous for CSM due to lunar occultation)
  Minimum number of sites, one 85 ft antenna site and wing site, two 30 ft antenna dual sites
  Typical number of sites, one 85 ft antenna site and wing site, two 30 ft antenna dual sites and two 30 ft antenna single sites,
  Maximum number of sites, two 85 ft antenna sites and wing sites, two 30 ft antenna dual sites, and six 30 ft antenna single sites
- b) Typical time interval of coverage by one site
  - i) For LM, 12 hours
  - ii) For CSM, 1.2 hours on, 0.8 hours off due to lunar occultation (As for the translunar and transearth phases, over a 12 hour interval the continuous coverage will be by the minimum number of sites for approximately 2 hours, the typical number for approximately 8 hours, and the maximum number for approximately 2 hours)

7.) LM Touchdown on Lunar Surface, LM Ascent and Prior to Rendezvous
- a) Coverage (Continuous)
  Maximum number of sites, two 85 ft antenna sites and wing sites, three 30 ft antenna dual sites, two 30 ft antenna single sites
- b) Typical time interval of coverage by one site,
  Approx. 1 hour during LM descent including lunar touchdown, 10 hours following lunar touchdown
  Approx. 1 hour following LM ascent to lunar occultation

8.) Prior to Transearth Injection
- a) Coverage (Discontinuous)
  Typical number of sites, one 85 ft antenna site and wing site, two 30 ft antenna dual sites, and four 30 ft antenna single sites
- b) Typical time interval of coverage by one site,
  Approx. 1 hour prior to lunar occultation

Figure 2 (continued)—Approximate Summary of MSFN Coverage for a Lunar Mission

9.) Transearth Flight
   a) Coverage (Continuous)
      Same as for translunar flight
   b) Time interval of coverage by one site
      Same as for translunar flight

10.) Entry
   a) Coverage (Discontinuous)
      Typical number of sites, one 30 ft antenna site, single or dual
   b) Typical time interval of civerage by one site, approx. 5 minutes

Figure 2 (continued)–Approximate Summary of MSFN Coverage for a Lunar Mission

One Spacecraft Coverage by:	20 MHz Local Oscillators per Spacecraft	Reference Loops per Spacecraft	Ranging Systems per Spacecraft	TLM Receivers per Spacecraft	Antennas* per Spacecraft	
					PM Modes	FM Modes
1 85 ft antenna site and wing site, 1 30 ft antenna dual site	6	12	6	12	3	2
1 85 ft antenna site and wing site, 2 30 ft antenna dual sites, 2 30 ft antenna single sites	10	20	10	20	6	2
2 85 ft antenna sites and wing sites, 2 30 ft antenna dual sites, 6 30 ft antenna single sites	18	36	18	36	12	4
Two Spacecraft Coverage by:						
1 85 ft antenna site and wing site, 1 30 ft antenna dual site	3	6	3	6	1.5	1
1 85 ft antenna site and wing site, 2 30 ft antenna dual sites, 2 30 ft antenna single sites	5	10	5	10	3	1
2 85 ft antenna sites and wing sites, 2 30 ft antenna dual sites, 6 30 ft antenna single sites	9	18	9	18	12	2

Figure 3–Summary Table of Certain Unified S-Band Equipment per Spacecraft

Mode (PM)	Site \ Range	100 mi	1000 mi	10,000 mi	50,000 mi	100,000 mi	240,000 mi
#2) Carrier, PRN Ranging Voice Normal TLM (51.2 kbs)	A) 85 ft Antenna Cooled Paramp	√	√	√	√	√	√
	B) 30 ft Antenna Cooled Paramp	√	√	√	√	√	√?
	C) 30 ft Antenna Uncooled Paramp	√	√	√	√	√	X
#4) Carrier, Voice, Slow TLM (1.6 kbs)	A) 85 ft Antenna Cooled Paramp	√	√	√	√	√	√
	B) 30 ft Antenna Cooled Paramp	√	√	√	√	√	√
	C) 30 ft Antenna Uncooled Paramp	√	√	√	√	√	√
#9) Carrier, PRN Ranging, Slow TLM, (1.6 kbs)	A) 85 ft Antenna Cooled Paramp	√	√	√	√	√	√
	B) 30 ft Antenna Cooled Paramp	√	√	√	√	√	√
	C) 30 ft Antenna Uncooled Paramp	√	√	√	√	√	√
#5) Carrier, Slow TLM (1.6 kbs)	A) 85 ft Antenna Cooled Paramp	√	√	√	√	√	√
	B) 30 ft Antenna Cooled Paramp	√	√	√	√	√	√
	C) 30 ft Antenna Uncooled Paramp	√	√	√	√	√	√
#7) Carrier, PRN Ranging	A) 85 ft Antenna Cooled Paramp	√	√	√	√	√	√
	B) 30 ft Antenna Cooled Paramp	√	√	√	√	√	√
	C) 30 ft Antenna Uncooled Paramp	√	√	√	√	√	√
#10) Carrier, Back Up Voice	A) 85 ft Antenna Cooled Paramp	√	√	√	√	√	√
	B) 30 ft Antenna Cooled Paramp	√	√	√	√	√	√
	C) 30 ft Antenna Uncooled Paramp	√	√	√	√	√	√
Mode (FM)							
#1) Playback, Voice, CSM TLM, Scientific Data	A) 85 ft Antenna Cooled Paramp	√	√	√	√	√	√
	B) 30 ft Antenna Cooled Paramp	√	√	X	X	X	X
	C) 30 ft Antenna Uncooled Paramp	√	√	X	X	X	X
#4) Television	A) 85 ft Antenna Cooled Paramp	√	√	√	√	√	√?
	B) 30 ft Antenna Cooled Paramp	√	√	X	X	X	X
	C) 30 ft Antenna Uncooled Paramp	√	√	X	X	X	X

√ – adequate signal margin, mode can be supported
√? – no signal margin, mode degraded but could probably be supported
X – mode cannot be supported

Margins are based on a TLM signal to noise ratio for 10^{-6} bit error probability, voice signal to noise ratio of 10 db for 90% word intelligibility and a PRN ranging signal to noise ratio of 0 db for 1 minute of integration.

Figure 4—Representative Mode Support for the Unified S-Band System with Adequate Signal Margin for Nominal MSFN and Spacecraft Parameters

REFERENCES

1. Lunar Orbital Mission Reliability Study Included in; October-December 1968 Quarterly Progress Report of the Manned Space Flight Network Study Program, Space Communications Group (CSC), Johns Hopkins University/Applied Physics Laboratory and Included in; Performance Evaluation of the Unified S-Band Ground System for AS-205, X-834-68-485, NASA, Goddard Space Flight Center

2. NASA, MSC Internal Note No. 68-FM-196, August 9, 1968 Apollo Mission G Spacecraft Reference Trajectory, Volume I, Reference Mission Profile (Launched August 14, 1969)

APPENDIX I

This appendix contains histograms of the total number (over the five missions status periods) of reported failures and repair times for some of the on site equipment categories. Included specifically are the Unified S-Band and 642-B computer areas.

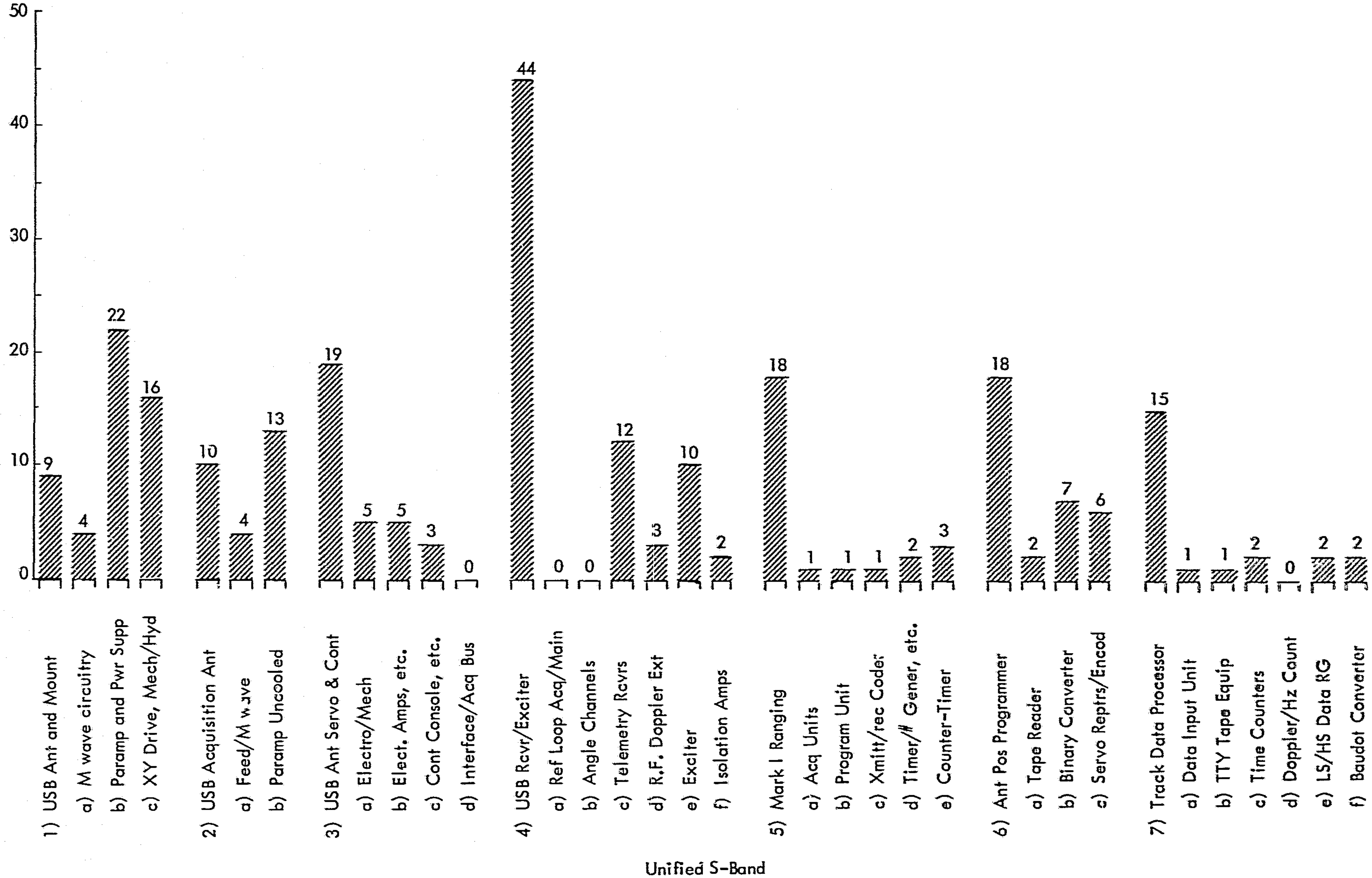


Figure AI-1—Equipment Subsystem Cumulative Failures for Missions AS-204, 205, 501, 502, 503

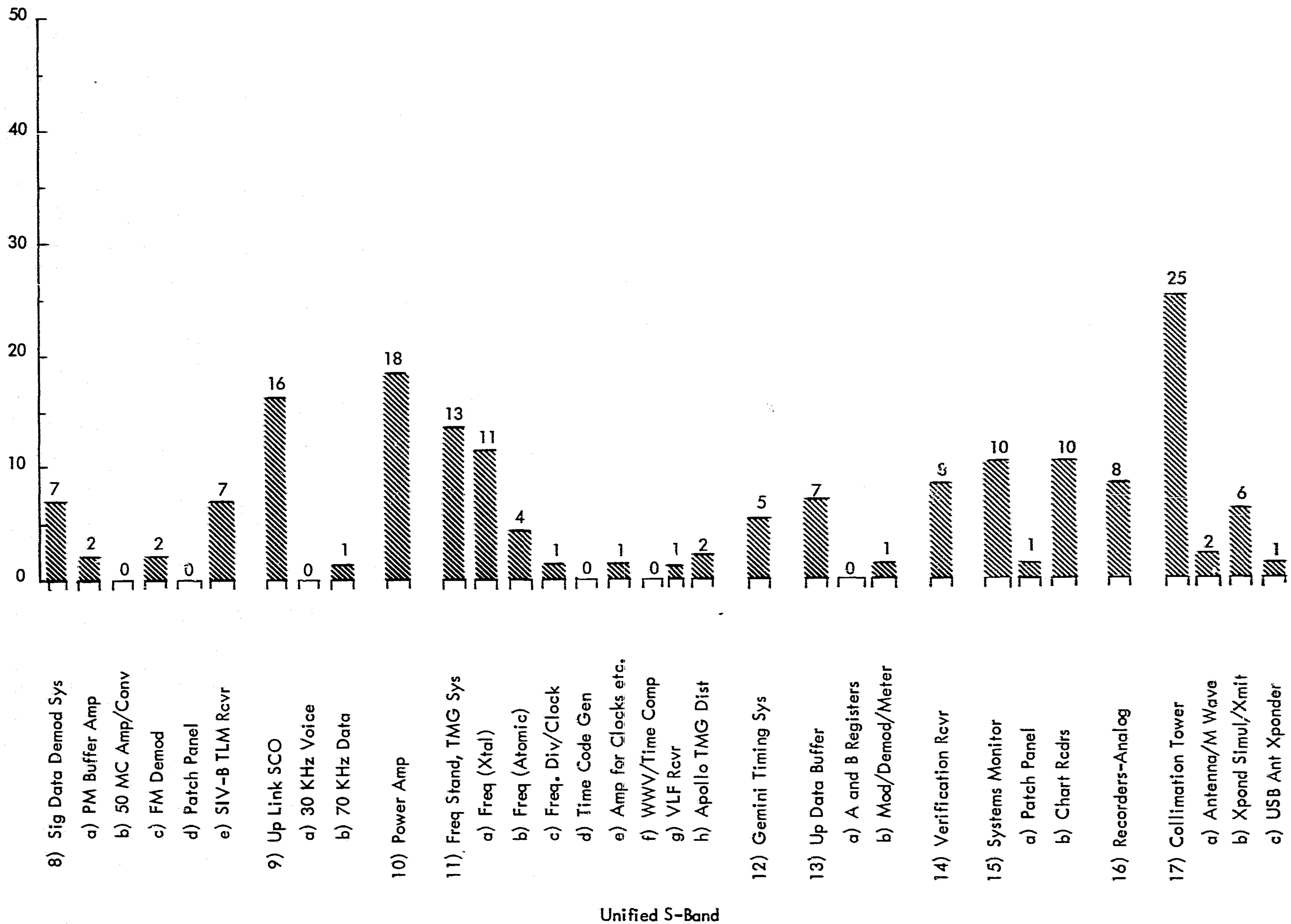


Figure AI-2–Equipment Subsystem Cumulative Failures for Missions AS-204, 205, 501, 502, 503

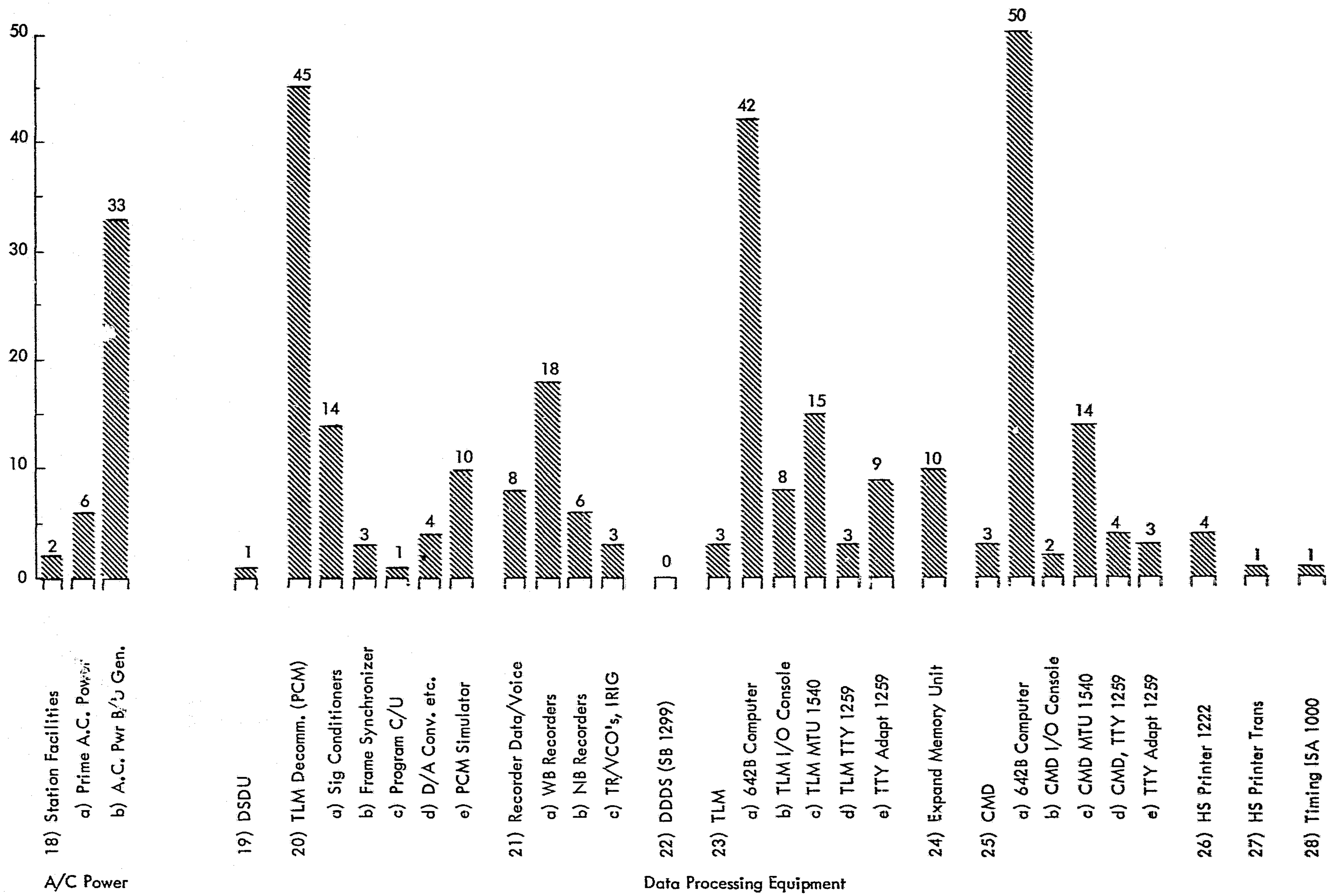


Figure AI-3—Equipment Subsystem Cumulative Failures for Missions AS-204, 205, 501, 502, 503

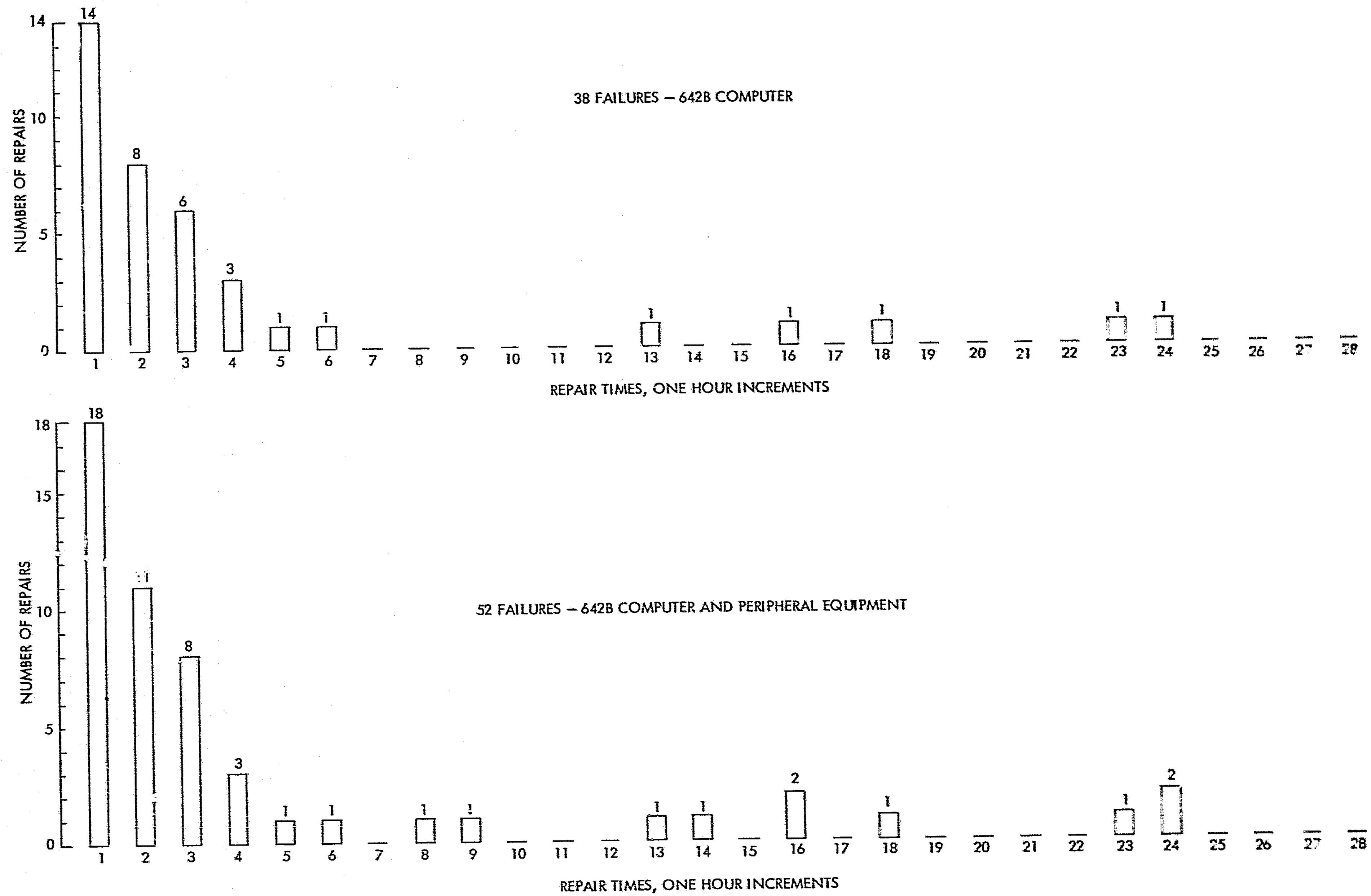


Figure AI-4–CMD 642B Computer and Peripheral Equipment Failures Repaired Within the First 28 Hour Period

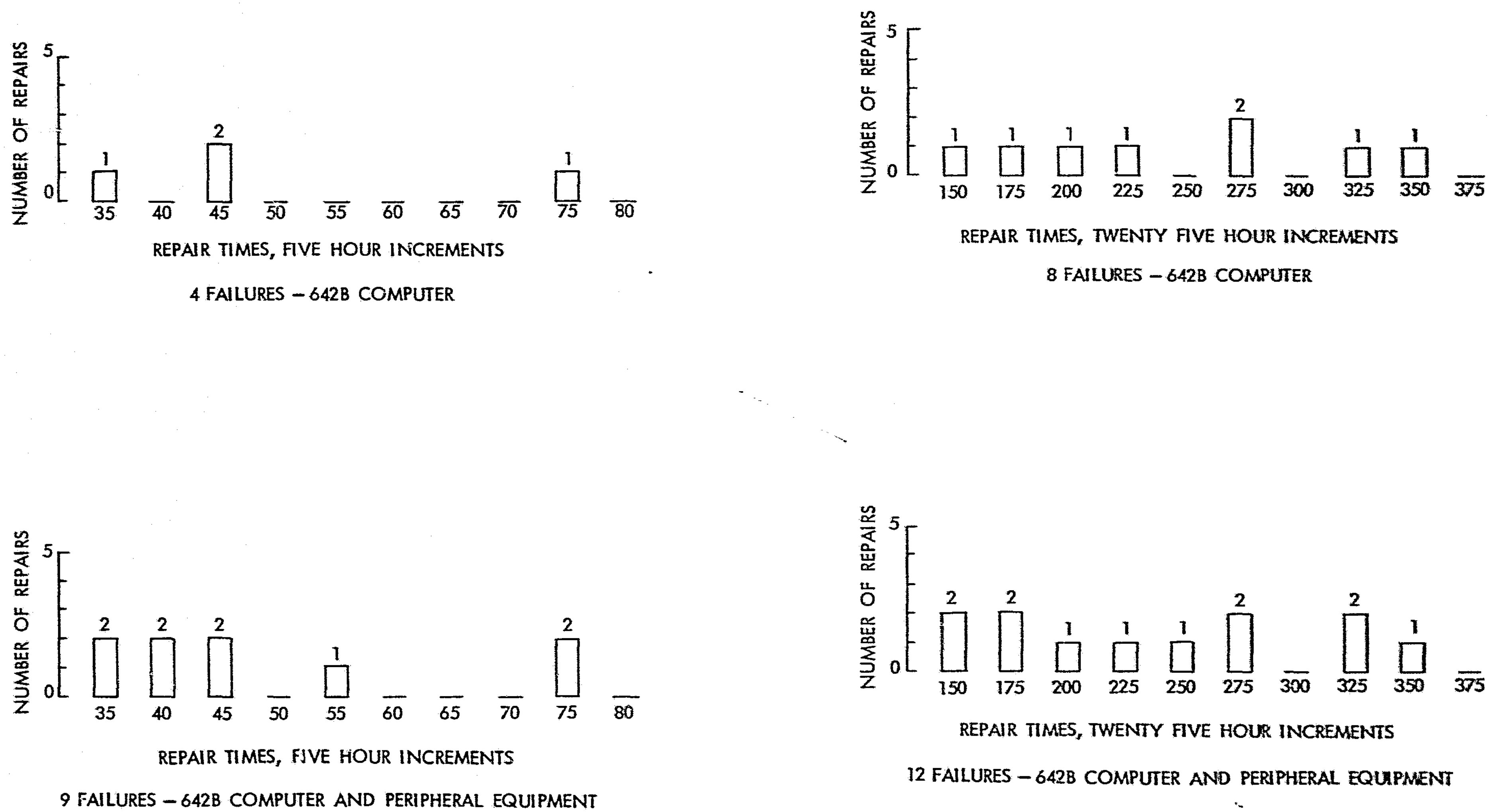


Figure AI-5–CMD 642B Computer and Peripheral Equipment Failures Inoperative for More than 30 Hours

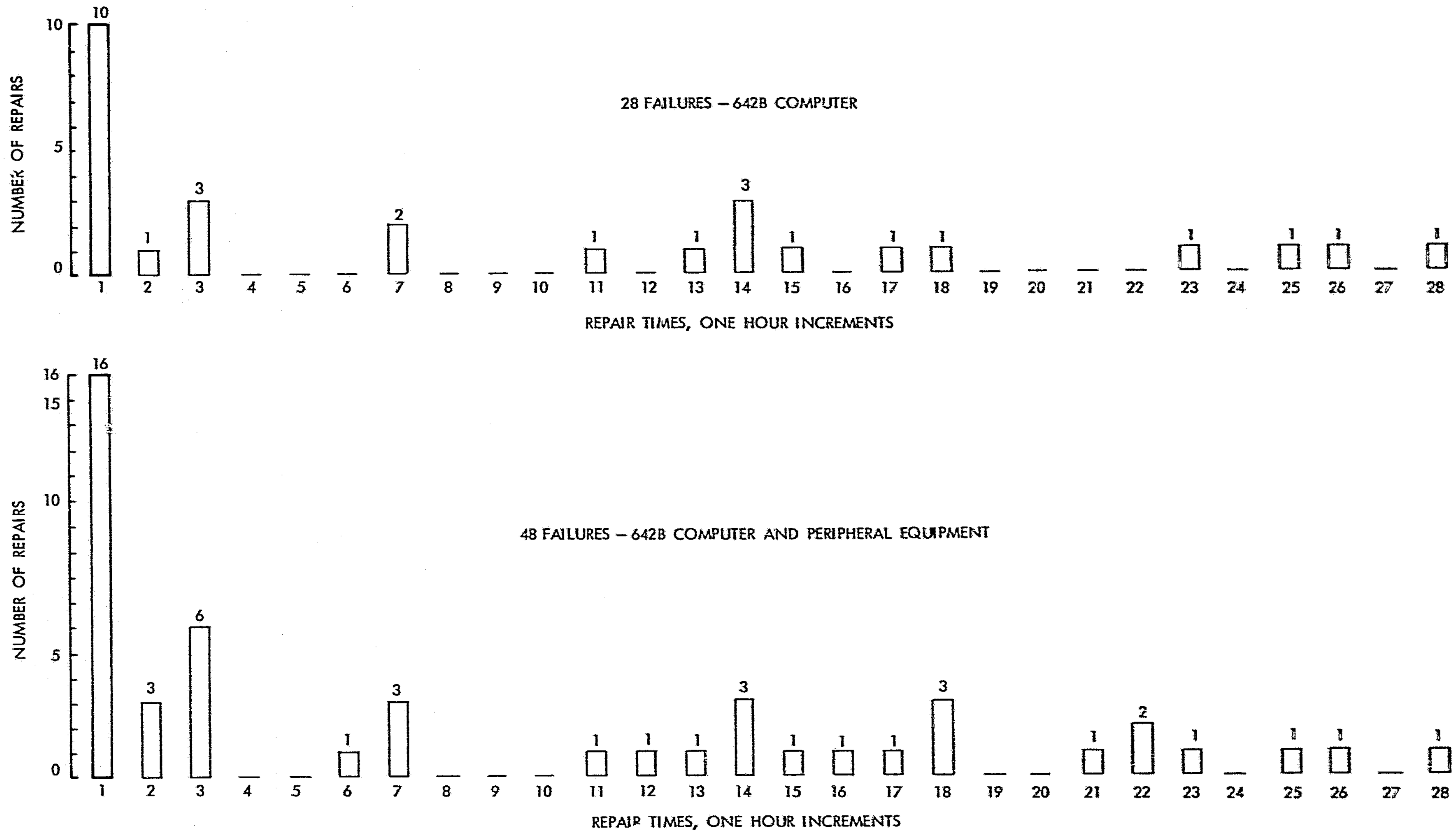
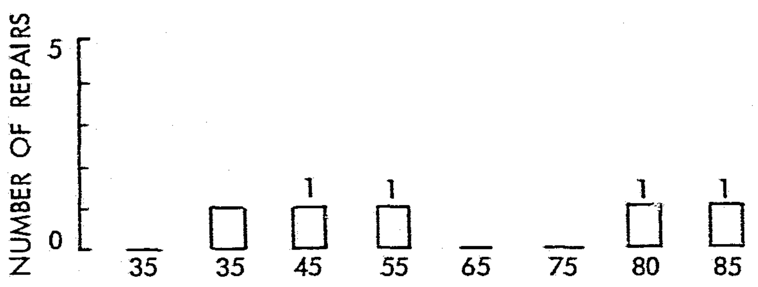
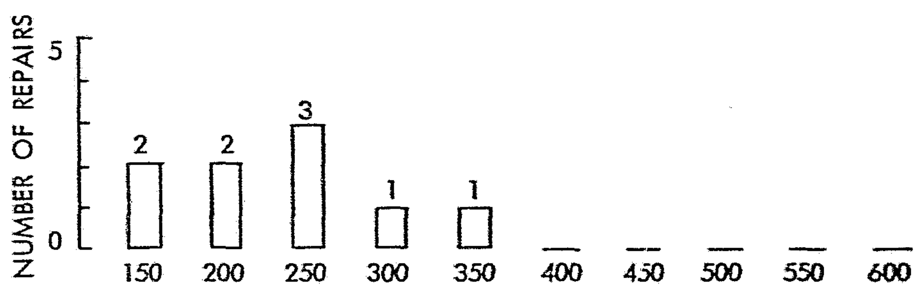


Figure AI-6–TLM 642B Computer and Peripheral Equipment Failures Repaired Within the First 28 Hour Period



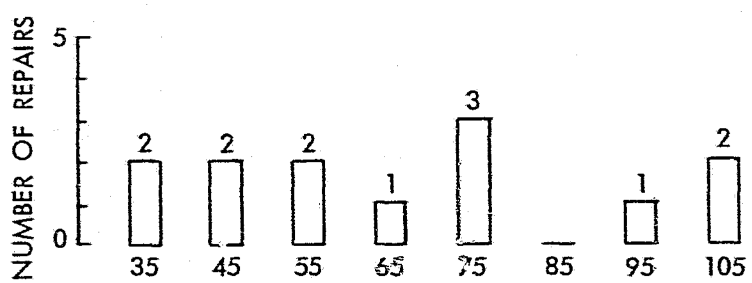
REPAIR TIMES, TEN HOUR INCREMENTS

5 FAILURES – 642B COMPUTER



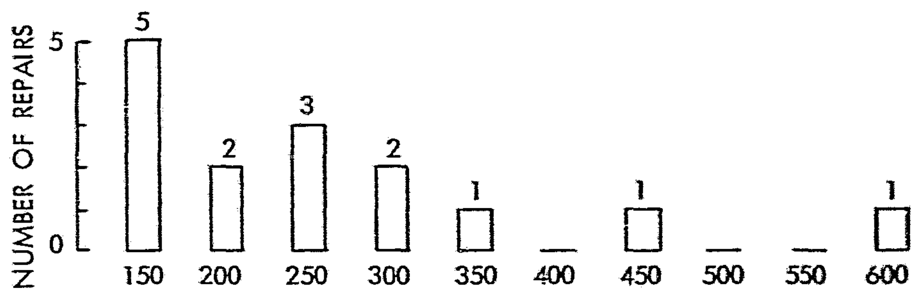
REPAIR TIMES, FIFTY HOUR INCREMENTS

9 FAILURES – 642B COMPUTER



REPAIR TIMES, TEN HOUR INCREMENTS

13 FAILURES – 642B COMPUTER AND PERIPHERAL EQUIPMENT



REPAIR TIMES, FIFTY HOUR INCREMENTS

15 FAILURES – 642B COMPUTER AND PERIPHERAL EQUIPMENT

Figure AI-7–TLM 642B Computer and Peripheral Equipment Failures Inoperative for More than 30 Hours

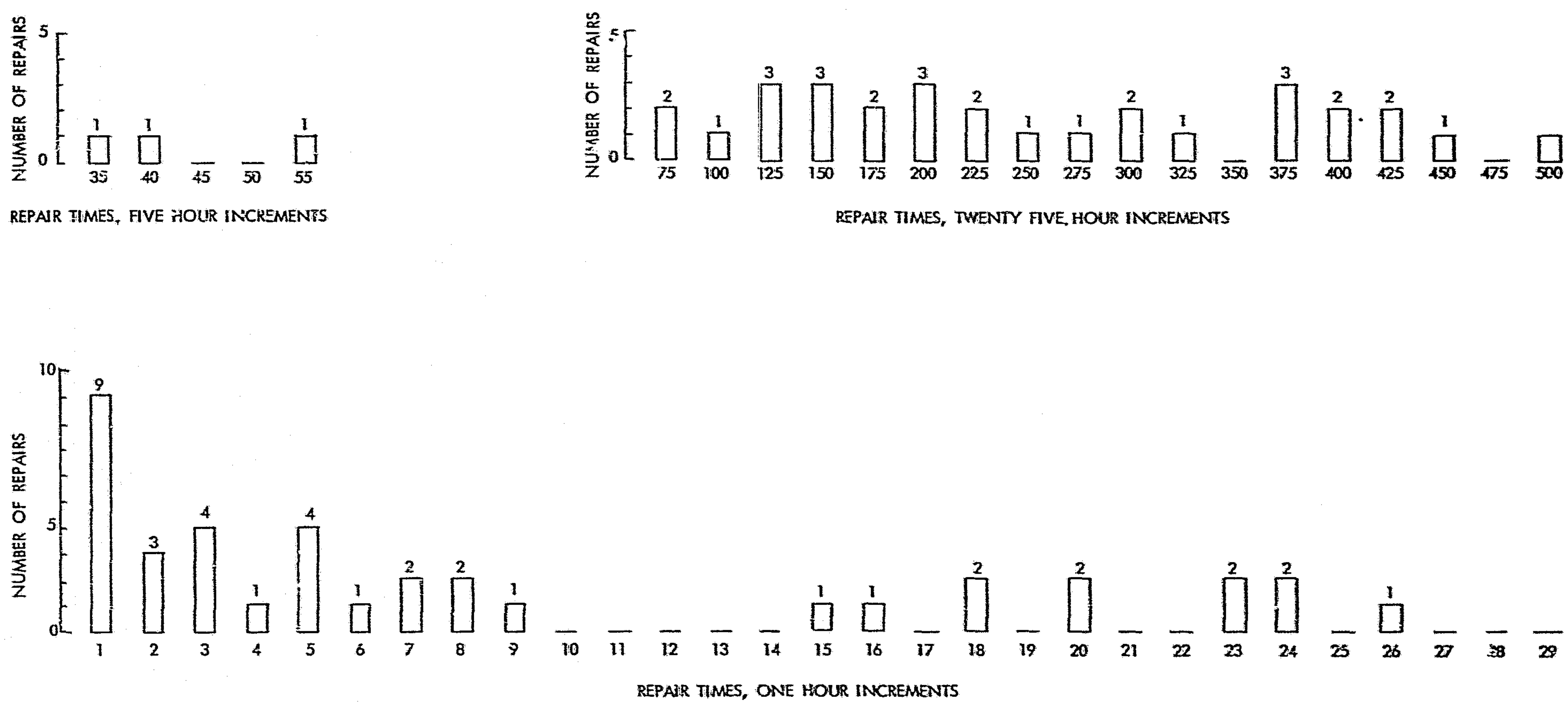


Figure AI-8—USB Receiver/Exciter Equipment Histogram of Repair Times